SILICON CHIP

MAY 2010
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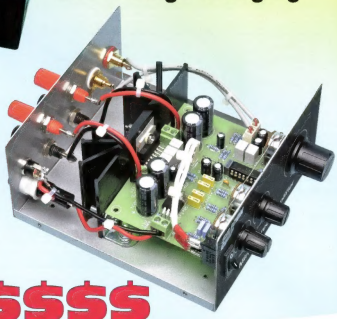

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Don't forget Mother's Day 9th May

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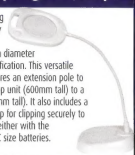

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Contents

Vol.23, No.5; May 2010 www.siliconchip.com.au

Features

12 Slash Your Factory/Office Lighting Bill
Want to save up to 50% on your shop/factory/office lighting power bill and get even more light into the bargain? Here's how – by Leo Simpson

20 A Look At The TDA7377 Quad 12V Amplifier IC
This versatile amplifier IC can provide four single-ended channels, two bridged channels or two single-ended channels and one bridged channel. Here's a look at how it works – by Nicholas Vinen

79 Review: Tektronix DMM4050 6½-Digit Multimeter
Full-featured instrument boasts 6½-digit readings, a graphic LCD readout plus trend plot, histogram, logging and dual measurement mode. Its short-term and 1-year accuracy figures are outstanding – by Nicholas Vinen

Projects To Build

26 A Solar-Powered Lighting System
Easy-to-build system combines a 5W solar panel, a 12V SLA battery and a smart controller with 3-stage charging. It runs the solar panel at maximum efficiency and is ideal for use in garden sheds, at a camp site or to power garden lights – by John Clarke

54 Build A Compact 12V 20W Stereo Amplifier
Amplifiers that run from 12V DC generally don't put out too much power. Not so with this unit. With a 14.4V supply, it delivers up to 20W per channel into 4-ohm loads at very low distortion – by Nicholas Vinen

66 Low-Power Car/Bike USB Charger
It charges USB devices from a 12V battery and consumes just 160μA on standby, so it won't flatten the battery if left connected – by Nicholas Vinen

74 Digital Audio Signal Generator, Pt.3
Final article on this versatile new test instrument has the driving instructions plus other useful information – by Nicholas Vinen

Special Columns

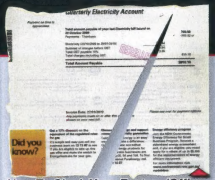
35 Circuit Notebook
(1) Momentary Switch Teamed With Latching Relay; (2) Digitally-Controlled Tone Filter; (3) People Counter Uses Light Beam Sensors; (4) Level Translator For A PIC Programmer; (5) Switching Balanced Microphones Using A Foot Switch; (6) PICAXE Traffic Light Controller

40 Serviceman's Log
The perils of salvaged computer parts – by the Serviceman

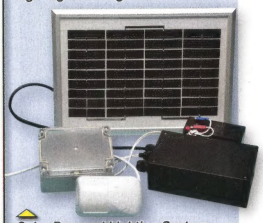
84 Vintage Radio
How AGC works and why it's necessary – by Rodney Champness

Departments

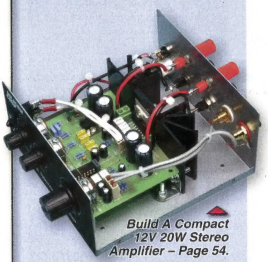
2 Publisher's Letter
4 Mailbag
53 Product Showcase
89 Order Form
90 Ask Silicon Chip
93 Notes & Errata
94 Market Centre



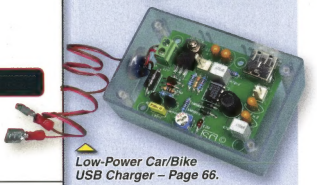
How To Slash Your Factory/Office Lighting Bill – Page 12.



Solar-Powered Lighting System For Gardens & Sheds – Page 26.



Build A Compact 12V 20W Stereo Amplifier – Page 54.



Low-Power Car/Bike USB Charger – Page 66.

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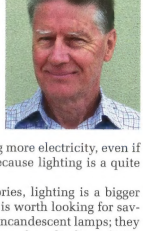
Publisher's Letter

Saving energy is not the issue



Back in the April 2007 issue we ridiculed the Federal Government's proposed ban on incandescent lamps (introduced by the then Liberal Environment minister Malcolm Turnbull). In fact, we had a fairly detailed article on why the whole proposal was impractical. None of what we said has ever been refuted (nor can it be) and the amount of energy subsequently saved in typical households due to the edict is vanishingly small. Most householders would not be able to identify any reduction at all from their electricity bills. In fact, I will wager that most households would now be using more electricity, even if they have substituted all their incandescent lights, because lighting is a quite small component of domestic electricity bills.

In the commercial area, in offices, shops and factories, lighting is a bigger component of energy use, typically around 30%, so it is worth looking for savings. However, most offices and factories use very few incandescent lamps; they mostly use fluorescent tubes or even more efficient forms of gas discharge lighting. But fluorescent lighting has become more efficient in recent years and this is the reason for the feature article on slashing lighting energy costs in this issue.

In the first instance, this exercise came about because all the lighting at the SILICON CHIP offices was looking decidedly dingy. The tubes were overdue for replacement and all the prismatic diffusers needed cleaning.

The outcome was that we got more light in the office and cut the energy use by half. But that only means that our total annual electricity use will drop by about 15%, since we estimate that lighting was about 30% of our total. By the way, I don't think the reduction in fluorescent light consumption will have much effect on our air-conditioning energy. It might reduce slightly in summer but there would be an equivalent increase in winter and would probably balance out over the year.

Ultimately, the estimated saving of about $400 a year is hardly worth worrying about, considering that our annual electricity bill is such a small proportion of our overall costs. So was it worth doing? Yes, but I would not advocate that all businesses do it unless they need to change fluoro tubes anyway. And while our payback period is quite short, it could be quite different in other establishments.

All of which serves to demonstrate that reducing lighting electricity use is only fiddling in the margins as far as overall energy use is concerned. If Australians really want to make a large difference in energy use, we would all need to make very big investments in public transport, drive smaller cars and so on. And while smaller cars are selling well, there has also been a big increase in sales of SUVs, so it suggests many consumers are not worried about fuel bills or energy use.

Unfortunately, it seems as though the only way that most consumers, and the country as a whole, will ever make a significant reduction in energy use is by governments taking action. But any action will need to be far more credible than the ban on incandescent lamps, subsidised installation of roof insulation, free energy audits, subsidised replacement of hot water systems with solar and heat pump systems and so on.

As far as electricity consumption is concerned, current Australian government edicts seem to be driven more by "carbon-pollution" reduction mantras than any sensible strategy. Those same governments seem to be unconcerned about the increasing number of coal mines, coal seam gas, natural gas and other schemes to exploit fossil fuels.

If governments were really concerned about carbon dioxide emissions they would go to nuclear power. Then nobody would worry about reducing electricity consumption, apart from the question of cost.

Leo Simpson

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Australia should recycle e-waste

I wish to comment on the March issue Publisher's Letter on the topic of e-waste.

Being a prosperous country also means we could afford to recycle. Dumping a few million tons of waste into landfill is equally expensive and as our population grows so will the waste. The inference that our prosperity is built on the throughput of goods from factory (foreign) to landfill encapsulates much of what is suspect in our current economic models.

I wonder how many people in Sydney realise that their garbage is now compacted into containers and trained, everyday, to a little town called Tarago, not far from Canberra. From the specially-built rail depot it is then trucked to an old open-cut mine called Woodlawn.

This solution to Sydney's garbage problem has quietly developed over the last decade and has been promoted locally as a clean solution: with methane capture to produce power, and a series of wind turbines around the area. As it happens Sydney's water deficit developed in parallel and the turbines took on another reason for their existence.

There is a common theme here with SILICON CHIP editorials over the last few years: commentary on obvious problems thrown up by an unfettered economic model coupled with rapid population growth. The commentary offered, essentially business as usual and ramp it up, is quite unimaginative.

This uncritical acceptance of the status quo illustrates the paradox which climate science presents to the Editor; accepting the science questions the status quo. Let's be quite clear that the fundamental science, ie, whether a gas absorbs and re-radiates particular wavelengths, is as sound as the science that enables the electronic and material wonder world that ends up in our spent mines.

I wonder which other aspects of science the Editor finds questionable. I suspect only those that might jeopardise our ability to fill up holes in the ground.

Rory Shannon,
Goongerah, Vic.

Comment: it is true that a great deal of Sydney's rubbish does end up at Woodlawn. It is also true that Australia does quite a lot more recycling than some other western countries. However, much of what is collected for paper and plastic bottle recycling also ends up in landfill simply because there is no market for it. We suspect that recycling of e-waste may be similarly non-viable.

As far as science is concerned, certain gases do absorb and re-radiate particular wavelengths. However, science has yet to come up with the answer to the riddle: why has the large increase in atmospheric carbon dioxide over the last 15 years not been accompanied by a corresponding large increase in global temperatures?

Free Insulation and Green Loans

I have just read your April 2010 Publisher's Letter on the insulation scheme and I totally agree. Unfortunately, the Green Loans program seems to have been even more mismanaged. There is a Senate Inquiry and there are horror stories appearing about how assessors have been treated. But that is not the real story. The real story is how bad the assessments were.

The assessment for my own house is an example. Total use for my house was 60,000 litres of water per year but the report lists 33,000l. It suggests electric-boosted solar hot water rather than off-peak and subtly suggests solar uses *zero* electricity. In addition, Victorian kWh to CO_2 figures were used for NSW. Victorian figures are in fact 30% higher than NSW.

If I implemented all the water savings I would be left with 3000l of water per year to use for drinking and washing. Replacing my washing machine would cost $1/year in electricity and 8kg of CO_2 with no water savings listed but they recommended that I replace it anyway.

The raw data they used contained the following errors: under-floor insulation was ignored; 13 external doors were listed for my house (I have 6); they listed my alarm as using 100W continuous whereas it is closer to 10W; my rechargeable Philips shaver is listed as using 400W for 15 minutes a day (the power supply is 6W).

Darryl Smith, VK2TDS,
Ingleburn, NSW.

DAB+ sampling rates not too low

Readers of SILICON CHIP may not be aware that Poul Kirk entered the radio broadcasting industry some 38 years ago as a technician at Perth radio station 6PR. He founded Poul Kirk Electronics (PKE) in 1975 where he continued to design and build broadcast studios as well as some recording studio equipment for other radio stations and recording studio clients.

PKE later concentrated exclusively on radio station studio equipment and made and sold a large range of practical, reliable and durable equipment to government and commercial broadcasters here in Australia and to overseas customers.

Many PKE designs became "Broadcast Industry Standards" which set layout and operational trends, still current today. He started Elan Audio in 1995 which still provides quality audio products to the broadcasting

industry. I have known Poul at an industry level for some 20 odd years and consider him a doyen in the design and manufacture of quality broadcast audio equipment. He is extremely qualified to talk about audio quality.

Whilst I do not disagree that the audio quality from our DAB Radio System is "not necessarily beautiful", I would like to challenge some statements made in Poul's letter in the March issue and provide your readers with some more information.

Firstly, Australia has adopted the DAB+ standard for its Digital Audio Broadcasting service. DAB+ uses AAC HE V2 (Advanced Audio Coding High Efficiency Version 2 or AAC+) as the audio compression system for Digital Audio Broadcasting (DAB). AAC+ was never designed for high fidelity; it was designed for high efficiency. In other words, it has the ability to fit more audio services, at an acceptable audio quality, into any given piece of Band 3 or L Band radio frequency spectrum, utilising the DAB standard as a transport mechanism.

DAB+ bit rates of 48 kilobits per second and higher, with light audio processing applied, can sound very good indeed! To talk about the old UK DAB standard, MPEG 1 Layer 2, in his article is irrelevant here in Australia. We just don't and never will transmit it. It is an old technology.

Poul claims "DAB+ is better than DAB but not twice as good". Unfortunately, in this case, he is simply incorrect. Blind listening tests carried out under scientifically controlled conditions by the EBU in Europe and by the ABC here in Australia show that 64kb/s DAB+ is perceived to be the same quality or better than 128kb/s DAB.

Poul also claims that many listeners in the UK complain about bit rates. This is not true – a few very vociferous listeners complain repeatedly on the internet, however market research carried out with listeners shows 80% are satisfied or more than satisfied with the audio quality. Radio is a mass market medium and the truth is that the mass market would prefer 20 services at a quality they are happy with rather than the four services they would get if the most demanding (256kb/s) bit rate discussed by Poul was deployed. Broadcasters would be irresponsibly squandering the valuable public resource of radio frequency spectrum if they did this.

Radio is about broadcasting to the masses and giving the consumer what they want. Time and time again

Simpler solution for solar boosting

I write in reply to your suggestion regarding solar hot water boosting on page 100 of the April 2010 issue, whereby you suggested the use of a timer to switch on the booster element after 4PM. There is an even simpler approach. Rather than install a timer, all that needs to be done is to connect the booster element to the normal tariff supply. When needed, the existing switch is closed for a period of only 15 minutes.

Thirty years ago my wife and I designed and built our house with energy and water conservation in mind. We have been using the above system since then without any trouble whatsoever.

Very rarely, if ever, is the total capacity of any hot water service required. If the total water volume is brought up to the thermostat cut-off then this is a waste of energy when not all of the hot water is required.

Less electrical energy is used and the cost at the normal tariff is less than the cost of heating a larger quantity of water than needed at the off-peak rate. Our solar system has a capacity of 300 litres.

When we leave on holidays the household electrical system is switched off. On returning from holidays, if the day has been overcast and the hot water is too cool, it is only a matter of 15 minutes before we can have a hot shower.

The only disadvantage is the necessity to remember to switch the booster off. Perhaps a 15-minute timed switch could be used in place of a normal switch.

Col Hodgson,
Wyoming, NSW.

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Mailbag: continued

Is our government totally inept?

Just a quick comment on the hot water heater fiasco. Correct me if I am wrong, our coal-fired power stations run 24-7 and one of the most efficient ways to store the unused electricity generated in the early hours of the morning is with off-peak hot water services. These are the very ones that have been ripped out under the Labour government-funded scheme and replaced with mechanical heat pump hot water services which run 24-7, need more maintenance, will not last as long and are least efficient in the cold of night. Am I wrong or is our government just totally inept?

Stephen Dyer,
Swan Hill, Vic.

Comment: while we are tempted to agree that our governments are inept, the picture is a little more complicated. Possibly our base-load power stations are using significantly more coal at night to maintain off-peak hot water than they otherwise would if this "optional" load was not being applied. We don't know if this is the case or not. Nor do we know what is the coal consumption when a power station is simply on "spinning reserve".

The best form of electricity storage is already being applied by the Snowy Mountains Hydro Electric Commission whereby it buys cheap electricity at night to pump water for generation of electricity at peak demand times.

We should point out that off-peak hot water systems can also be powered for substantial times during the day, so if heat pumps are being substituted, there may be an overall reduction in energy usage. Having said that, we think that all the subsidies which are available to people to convert their off-peak hot water systems to solar, heat pump or gas-fired systems have very little overall energy benefit compared to their high cost to the taxpayer.

In other words, as with many government carbon-pollution reduction initiatives, no cost/benefit analysis has been done or published.

the consumer has demonstrated they value choice and convenience over quality. You only have to look at the massive uptake of MP3 players around the world to realise this. Commercial radio, in particular, has to give the audience what they want in order to survive and thrive. In Australia, commercial radio stations are broadcasting with bit rates as low as 32kb/s and as high as 96kb/s.

The 64kb/s used by most Australian commercial broadcasters has been proven to be equal to or better than the 128kb/s used by UK broadcasters, which has been shown to be perfectly acceptable to the vast majority of UK listeners. It should also be noted that the national broadcasters, ABC and SBS, transmit at bit rates of between 48 and 80kb/s depending on the service.

Time spent listening and listener ratings figures will tell if the audiences value the higher bit rate services in Australia and tune into these stations for longer. If it is demonstrated that consumers value the high bit rate services, then other broadcasters would be foolish not to follow this lead.

However, listeners value content more than quality, a fact clearly demonstrated by the fact that the most popular stations in Australian cities are usually AM services.

A DAB+ multiplex system here in Australia can fit 18 DAB+ audio services at 64 kilobits per second at equal to or better audio quality than the maximum number of nine DAB audio services at 128kb/s that could fit into the same system in the UK.

Try listening to FM or AM radio whilst driving a car in and around the CBD of Melbourne and other mainland capital cities. The multipath distortion on FM is atrocious and the man-made interference on AM makes listening virtually impossible. Recently, I successfully installed a DAB+ radio receiver in my own vehicle and integrated it into the existing audio system and antenna system on the car. The results driving around Melbourne and its suburbs are excellent!

It should be noted that the big three vehicle manufacturers here in Australia are looking to line fit DAB+ receivers into their vehicles within the next few years, so DAB+ listening in cars will become more prevalent.

I can now listen to any AM radio station simulcast on DAB+ in crystal clear digital sound. It is so good that one can even hear the announcers breathing in between words. It is like being in the studio with them. All this is achieved at a bit rate of somewhere between 32 and 64kb/s depending on the station you're listening to at the time. If you listen to talk-back, sport or news radio on AM, then DAB+ is for you.

FM stations simulcast on DAB+ are free from multipath distortion and man-made interference. Personally, I find the lighter audio processing used on DAB+ much easier to listen to than the heavier audio processing used on FM. Again, the majority of FM stations transmit their DAB+ audio at 64kb/s. The audio quality is very good.

Add to this, a plethora of new radio services only available on DAB+ for the listener to consume for free and I believe Australia is on a winner!

Steve Adler
Woodforde, SA.

GPS car computer enhancements

I love the GPS Module (GPS Car Computer, January & February 2010) and will be building one as soon as I can source the components.

I would suggest the spare inputs could be used with piezo gyroscopes to integrate pitch and roll and an accelerometer to measure G forces. This way it might be possible to download a log of an aerobatic sequence and see how you went; much like the Red Bull Air Race coverage.

Mark Bolton,
Perth, WA.

NMR spectrometers now use Fourier Transforms

In reading The Serviceman article of March 2010, I was reminded of my early experiences with NMR spectrometers, when I was a PhD student in Boston, MA, in the early 70s. Fortunately, we were allowed to service

our own equipment (if we dared) and I learnt a lot working with a Varian T-60, whose manuals were well laid out with plenty of waveforms. NMR spectrometers are particularly useful to synthetic chemists and detect atoms (nuclei) with magnetic spin, a property which means that they can exist in low and high energy states in the presence of a magnetic field.

Fortunately, hydrogen is one such nucleus and we can deduce a lot about chemical structure from just where the signal occurs and how it is split. The position in the spectrum indicates the sort of structure in which the hydrogen may be found and the splitting tells us about its near neighbours in the structure.

The need for signal integration derives from the observation that the signal intensity is proportional to the number of hydrogen atoms producing the signal. To do this you need a very homogeneous magnetic field as a hydrogen spectrum is only about 10ppm wide and so several 10-turn pots are used to adjust the field homogeneity.

Sample spinning is then used to average out the remaining inhomogeneities. As a result, even with these early machines, we could resolve spectral lines 1/1000th of the spectrum width or better. We soon became adept at tuning the machine, changing transmitters and receivers so we could use it to detect fluorine atoms and effecting repairs, which were greatly aided by the manuals, although the integrated circuits probably only contained a few transistors. However, I did finally solve one problem which puzzled us for some time.

In normal use, a recording pen moves across a chart, drawing out the signals. Its movement is linked to the magnetic field so that each signal is recorded according to its position in the spectrum. On this occasion, the pen would be as quiet as long as there was no signal but as it approached any signal and passed through it, it became

Substitute transistor for the Hacker radio

I have just read the Serviceman's March 2010 article in which he discusses repairing a Hacker Sovereign RP18 radio. He mentions having problems with the ubiquitous (for the era) AF117/AF117N transistors. There were manufacturing issues with this and other AF*** transistors which has resulted in the failure of nearly all of them, including "new old stock" replacements.

A direct replacement transistor is the NTE160, which is available reasonably easily from suppliers here in Australia, one of them being RS Spares. This transistor does not suffer from the same manufacturing problems as the AF117.

I would recommend replacing all the AF117s with the NTE160 to prevent seeing this radio back on the repair bench for the same fault.

Best regards and congratulations on an enjoyably diverse magazine.

Ron Pond,
Maddington, W.A.

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Mailbag: continued

Frothing at the mouth

The March issue certainly had some interesting letters and articles. I feel that there are some letters in particular that need replying to.

Your comment to Graham Hunt, referring to wind generators and desalination plants, was that there is in fact nowhere on Earth where the wind blows continuously, 365 days a year. Those places on Earth that have the most wind do not have it at sufficiently high enough speeds all of the time to generate consistent power. As for the "roaring forties", anyone who has sailed across Bass Strait knows that the wind does not blow all the time.

I hope Paul Garson was being sarcastic and not as silly as the electricity authority appears to be. Blackouts are not caused by people using air-conditioners or plasma televisions. How dare people in 40°C plus temperatures even think of cooling themselves down – they should obviously die from heat stroke. The real reason for blackouts is the failure of the power companies and the Government to adequately resource the infrastructure required for the growing population, regardless of how much power is being used.

Unless people are rich and/or stupid, they are not and can't be wasting power at the extortionate and increasing charges that are being levied on them, not because of cost but greed. This means bigger profits and more money in CEOs' and shareholders' pockets, at everyone else's expense.

Commenting on the letter by Rob Holmes on global warming sceptics, there has not been a shred of concrete indisputable evidence to show that what we are experiencing is not natural. Just because there are higher or lower (not global warming) temperatures than we have experienced in the infinitesimally short time we have been on this planet, does not offer proof of anything.

Weather patterns, and I say weather patterns as the term "climate change" is grossly misused by people who apparently don't even understand its definition, have many external influences, like the Sun and the effects of axis shift. Not to mention the amount of seismic activity we have been experiencing over the last six or so years.

The Earth is releasing pressure build-up which is normal. This is responsible for the changes in ocean levels, not global warming.

However the climate change idiots do not take any of this into account. Now we have those clowns in the UN and Copenhagen fudging figures because they are more interested in covering up their incompetence than admitting they are wrong.

Nothing we do in this world is without some risk. If we were afraid of taking some calculated risk, we would still be living in caves. Nuclear power is a safe and clean energy and it is pretty much the only answer.

Concerning the article on Digital TV by Alan Hughes, Australian television networks, especially the commercial ones, are anything but short of funds. They can easily find hundreds of millions of dollars to throw at the football alone. However, they constantly cry poor when people want more Australian programs or more funding for them. The lack of imagination in Australian television programs and movies is an absolute disgrace.

New Zealand has surpassed us and no doubt earns much more through their television shows and movies than we do. If New Zealand can make films like Lord of the Rings, King Kong and District 9, there is no excuse or reason why we can't make films of this calibre in Australia. Digital television is a joke. The networks will not pick up their game unless forced to and we probably will not see MPEG4 in this country unless they pushed.

Tony Joyce,
Macquarie Fields, NSW.

increasingly noisy. We could find no fault with the drive mechanism and its interface and it took me some time to deduce that one of the 10-turn trim pots had developed a noisy wiper contact. This caused small fluctuations in the magnetic field but as long as no signal was being detected it made no difference. As the pen approached a signal, the field would drift in and out with the pot noise and this produced the noise on the chart.

Such machines are now obsolete and we have moved to superconducting magnets to increase the field strength, because the signal intensity increases with the magnetic field and so less sample is needed. The machines tend to be designated by the hydrogen resonant frequency in MHz, so the T-60 operated at 60MHz. Even simple scanning methods, such as I used, are obsolete and spectra are produced by applying an excitation pulse and generating the spectrum from a Fourier Transform of the decay signal. This has the advantage that many spectra can be acquired and averaged before the transform to increase the signal to noise level.

The T-60 had a button marked CAT (Computer of Average Transients, if I remember correctly) but I've never seen one in practice and the time needed to acquire data would be prohibitive.

Dr Graham P. Jackman,
Oakleigh East, Vic.

Valve & transistor radio commentary

I always enjoy reading the 'Serviceman's Log' and found his foray into early valve and transistor radios, (March 2010), made interesting reading.

The trap of connecting the first electrolytic capacitor directly to earth instead of the transformer centre tap (when back bias is employed) is one that many restorers have fallen into and is made easier when a set has been "fiddled with" or a circuit is not available. The advice given to him that the value of the first electrolytic is important is in fact correct. Valve manufacturers typically specify a maximum peak cathode current for

their rectifiers and their data sheets quote a maximum value for the first electrolytic in combination with a minimum value of anode supply impedance to keep this current within safe limits. The anode supply figure is usually the impedance of each half of the secondary winding of the power transformer.

The difference between 16µF and 22µF is of no consequence and is probably overlapped by the tolerances of the two values. Where trouble starts is when a repairer decides that "bigger must be better" and fits 47µF or 100µF units and this can certainly result in a shortened life for the rectifier valve.

Valve output transformers have a fairly high mortality rate, often as a result of electrolysis. The laminations are usually connected to the chassis, at earth potential while the primary winding has in the order or 250V applied. Add a little moisture and a leakage path between the two is soon completed, resulting in failure of the fine wire used for the winding.

This was a particular problem in some battery sets where the on/off switch only disconnected the filament voltage and left the HT permanently connected. One way to overcome this problem was to remove the potential difference between the laminations and the winding. The first method used to achieve this was to mount the whole output transformer on a panel insulated from earth and connect the laminations to B+. Some filter chokes were also mounted in this way for the same reason.

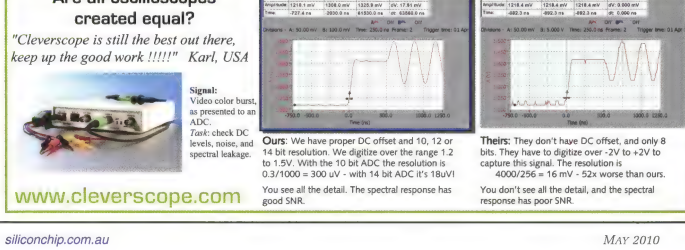
In later years, the transformer manufacturers produced a range of 'Isocore' transformers where the complete transformer was sealed in pitch and housed in an isolated metal case with the core internally connected to B+. This also reduced the number of "nasty surprises" for repairers!

I have not seen a set where the complete loudspeaker is connected to B+ and maybe the Philips set mentioned in the article also had some other modifications made to it.

The AF116/7 series of transistors, as used in the Hacker Sovereign and many other sets of the era, were notorious for developing shorts between the case shield and the other electrodes. This appears to have been some form of metal migration and I am not sure if the problem was ever solved with these types. The good news is that cutting off the shield lead can often restore normal operation. A number of manufacturers who used this series of transistors did not use the shield connection and removed the lead before assembly. I have not seen an instance on a radio where removal of the shield connection caused any stability problems. Since these alloy diffused types are not plentiful these days, any trick that can extend their life is worth a try.

By 1968, Philips had re-packaged these transistors in the smaller TO-72 case as the AF126/7 series. I have not heard of similar shorts occurring in these types.

Regarding the ongoing failure of the IF amplifier in the Hacker, the AF117 has a collector-emitter voltage rating (V_{CER}) of 32V so it seems unlikely that a variation on



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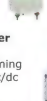

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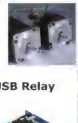

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Mailbag: continued

the 7V rail could cause the problem. Perhaps there is another "gremlin" and maybe we can look forward to a follow-up article?

Warwick Woods,
Glen Iris, Vic.

More spelling errors

I know that these are not your spelling errors but on the page opposite Alex Danilov's letter (SILICON CHIP, March 2010, page 4) is an advertisement for solar panels which feature "3.2mm TAMPERED GLASS". One would hope that the product's quality control is better than that applied by the copy writer.

Rob Holmes' letter that follows Alex Danilov's one has "global warming deniers". No-one is concerned with the size of these people but there is a group of "Global Warming DENYERS". By the way; all three errors will cheerfully pass a mindless computer spell checker.

Brian Wilson,
Curtin, ACT.

Most people don't care about the latest technology

So Alan Hughes is already bored with MPEG-2 DVB-T and thinks the standards should be changed; just what those of us who've already accumulated MPEG-2 digital boxes for umpteen TVs and VCRs want to hear! And just how long are digital boxes producing a 625-line composite video output going to be available anyway? When we're up to MPEG-10? I think not.

Like most technology pushers, I think Alan is oblivious to the fact that most of the population is not only not interested but find it inconvenient having to constantly change and replace equipment to suit the whims of these people. I know it's a hard concept to grasp but life actually does go along just fine with TV channels sharing the FM band, listening to our AM and FM radios, watching VHF low-band transmissions on our analog TV sets and whatever else the technology pushers dislike.

Let me ask this question to the technology addicts: is the real quality of your life really better surrounded by all these mass-produced, short-lived fads (or is it more appropriate to call them "electronic fashion accessories")? Are such items a cure for unhappiness or any other lack of well-being one could name? Put technology into medicine where it really can make a difference, not so people can be shut indoors all day watching mind-numbing TV and adding to the obesity epidemic.

The fact is, we already have the best TV system in the world with the 625-line PAL transmissions and I do not know anyone personally who felt it lacking in quality to the point of thinking something "better" was required. In fact, from my experience installing television aerials, it's often hard to convince the customer to go with a good ghost-rejecting design rather than one of the cheaper aerials.

Ghost-cancelling and definition-enhancing signals were actually developed for analog TV in the 1980s but little was heard of them, because again the consumers weren't interested. Stereo sound was also a short lived fad with few actually wanting it. However, all these add-ons, including colour, were compatible and viewers could keep using their existing sets. As a result, I still can (and do) watch sets produced in the 1950s, with the additional signals simply being ignored.

My experience in dealing with the average non-technical consumer is that the only thing making most people get digital TV is the fear of the analog transmissions being turned off. This, of course, is purely political when in actual fact both systems can operate side by side indefinitely and keep everyone happy. Alan and Co can have 1000s of lines, 3D, IP-addressable brain implants (no need for any display then) or whatever else is in vogue at the time, replacing their gear every few months if that's what they want, whilst leaving the decades-old proven and reliable system for those happy with it.

A case in point: having installed digital boxes for an elderly neighbour for this very reason, changing channels is no longer the simple process of turning the turret tuner to the required channel or pressing the button labelled with the

MacBook review is too enthusiastic

I am not sure how to phrase this. As a fairly regular buyer of SILICON CHIP I have assumed it to be reasonably unbiased and very informative. The March 2010 review on the MacBook has disturbed my confidence.

This email is from a MacBook Pro OS 10.5 (ie, Leopard) using Mozilla. We have various other computers and systems in the house with IBM W98, XP, Win7 etc and Linux – Ubuntu and Debian plus a Puppy too. So all sorts with various pros and cons.

This Mac is using a Logitech wheel mouse because of the inadequacy of the Mac. We use Mozilla because of the inadequacy of the Mail program. We still (after two years) have problems with the Mac printing emails in super small font (I am over 50) and we still have problems with the one corner window expansion and "dumb" windows compared to Linux on a Mac and so on.

The worst part was the lack of help when we first got the Mac, with horrible phone support and shop tutorials (my view). We only had dial-up when we got it although we do now have broadband.

We found "The Missing Manual" (by David Pogue from O'Reilly Press) to be 800 pages of excellent advice on how to use the secret commands. The title says all you need to know about this excellent piece of hardware and design and the "more excellent" marketing.

I do, however, suggest YOU take the Mac home (disconnected from the internet) and try to use it. Read the Preface of Pogue's book. It's not just me.

Bob Barrett,
via email.

Kevin Poulter replies: I have four Macs and my wife uses a "vintage" Mac 9600 on OS 8.5, all used daily. Until last year I also used a PC daily. The MacBook got me excited, as everything works so well. I would not have written such a glowing test of any previous Mac.

I'm not sure why you use a wheel mouse. I like them too but have not used mine for months, since mastering the track pad. Mac's mail system has suited me for years and if it displays text too small, this can be enlarged to huge text in Mail -> Preferences -> "Fonts and colours". I totally understand less than 20:20 vision and there are many ways of assisting readability, from the new super-bright screen, to the easy magnification of anything by moving fingers on the track pad, to a choice in preferences for the computer to permanently enlarge file names.

Some of your issues are not fully explained so I cannot comment, however my Mac's mail on ADSL2 works well.

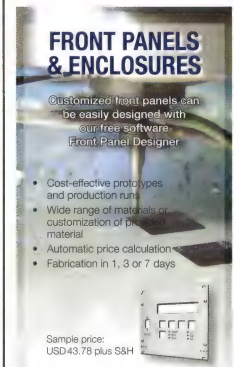
With every computer brand there will be lemons and "learning curves". I agree with your complaint about lack of instructions. That's why I chose a long-respected supplier who accepts calls for assistance. I also read many magazines and am a member of a Mac club.

channel number. Now, the only way to do so is via a complicated remote control which is a hindrance rather than a convenience.

Initially, my neighbour was under the impression her sets were too old and wouldn't be usable with the DVB-T service. This made me wonder how many sets have been thrown out simply because their owners didn't know that a digital box (with external VHF modulator if necessary) will work on any set; even one made in 1956!

On a completely different topic, regarding the Serviceman and his curiosity about the valve radio speaker transformer laminations being connected to the B+ supply, that is actually common practice. The reason this is done is to prevent the primary winding going open circuit due to electrolysis caused by the minute leakage currents flowing between the winding and the laminations. However, in most such sets the laminations are insulated from the mounting clamp. Where the clamp is live, one could reduce the shock hazard by connecting the transformer laminations to B+ through a high value resistor, eg, 220kΩ, instead of directly.

John Hunter,
Hazelbrook, NSW. SC



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Most offices, factories and shops waste a lot of money in power for lighting. How would you like to save up to 50% of your lighting power bill . . . and get even more light into the bargain? We show you how – and have the measurements to back it up!

In a typical commercial building, lighting accounts for about 30% of total energy consumption.

Air-conditioning amounts to about 50%, while the remainder is taken up by office equipment such as computers, copiers, printers and so on. So how can we reduce overall power consumption?

Over the next few years this question will become far more pressing as electricity tariffs increase dramatically.

Since air-conditioning is the main energy user, it behoves the building or office manager to ensure that everything has been done to minimise energy use. In particular, attention must be paid to anything which generates heat in summer, which means the air conditioner has to work even harder – and use even more energy – to overcome.

Regular servicing of the air-conditioning system (especially cleaning the filters, which you can usually do yourself), monitoring of temperature settings in winter and summer, ensuring that doors are kept closed to stop drafts and so on are all important. Ultimately, measures like window tinting and double-glazing can provide further energy savings but the initial investment will be a lot higher.

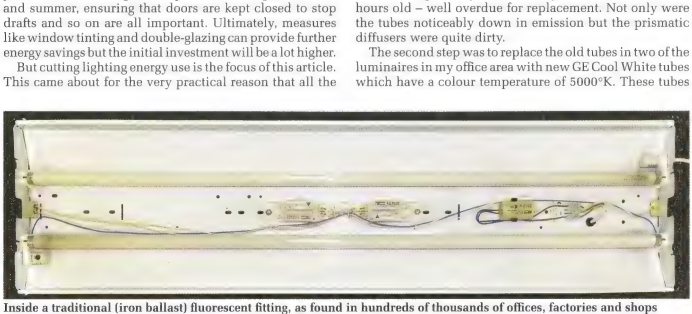
But cutting lighting energy use is the focus of this article. This came about for the very practical reason that all the fluoro tubes in the SILICON CHIP offices obviously needed replacing.

In most offices, the approach would be to have all the tubes and starters replaced, together with cleaning the diffusers. That should be done every few years as a matter of course but this simple approach will not provide any energy savings. We were looking for significant savings.

Our first step was to measure the light levels around the office and it must be stated that they ranged from just adequate to poor. In an office of about 12 x 8 metres, the levels ranged from under 150 lux to about 280 lux, at best. The average level was about 210 lux. The whole area is lit by 12 twin-36W fittings, more correctly referred to as recessed luminaires (or in the trade as "troffers") which have prismatic diffusers.

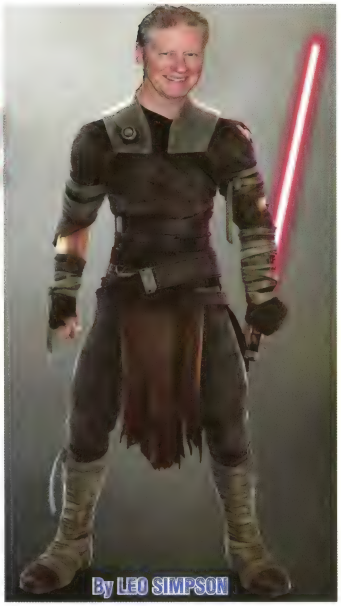
In our case, as we moved into this building in 2004, the tubes were probably at least six years, or around 16000 hours old – well overdue for replacement. Not only were the tubes noticeably down in emission but the prismatic diffusers were quite dirty.

The second step was to replace the old tubes in two of the luminaires in my office area with new GE Cool White tubes which have a colour temperature of 5000°K. These tubes



Inside a traditional (iron ballast) fluorescent fitting, as found in hundreds of thousands of offices, factories and shops around the country. The two ballasts are in the middle, the power factor correction capacitor is on the right, while the starters are mounted on the ends. Note the blackening of the tube ends – a sure sign these tubes are on the way out.

CTORY/ G BILL!



are significantly whiter than the old tubes which have the distinct greenish hue (or "cast") of conventional fluorescent tubes. With the new tubes fitted, the light measurement went from 210 lux to 320 lux. This was much brighter but then we decided to try some Mirabella Tri-Phosphor tubes, again with a colour temperature of 5000°K.

These were much brighter again; too bright in fact. So we opted to have just one Mirabella Tri-phosphor in each fitting. This gave a light reading of 270 lux, well above what we had started with.

But we also wanted to try NEC quad-phosphor tubes which are claimed to be 15% brighter than tri-phosphor tubes. While slowly becoming more popular, they're not the easiest things in the world to buy (as yet, they're not in your local supermarket), nor are they cheap.

But we found them in a Bunnings Hardware store and purchased a couple to try out.

Incidentally, we also found out while shopping around that it is getting almost impossible to buy older, single-phosphor tubes any more. The vast majority of tubes on the shelves of both supermarkets and hardware stores were in fact tri-phosphor. So at least that's a good start!

We're getting a bit ahead of ourselves here but we were so happy with our tests we bit the bullet and purchased a box of 25 NEC quad phosphor 37W tubes from our local electrical wholesalers, John R Turk, here in Brookvale. The cost was $316.25 including GST, or $12.65 per tube. This might seem expensive for 25 fluoro tubes but it is much cheaper than buying them retail.

With a single NEC quad-phosphor tube in each luminaire, the light was up dramatically to around 310 lux. This was great so we then did the same for six twin-36W luminaires – fitting one quad-phosphor tubes for the old tubes and cleaning all the prismatic diffusers and white-painted surfaces of the light fitting. This brought about a dramatic change. The final light reading on my desk was now 330 lux.

By contrast, here's a modern fluorescent luminaire fitted with a single electronic ballast (centre-right). Note the absence of a power factor correction capacitor and starters – they're not needed with the electronic ballast. The downside of this particular fitting is that it cannot drive a single tube – you must have two fitted. But they should last longer.

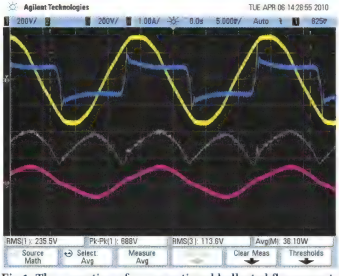


Fig.1: The operation of a conventional ballasted fluorescent light. The yellow trace is the incoming 230VAC waveform while the blue trace shows the waveform across the fluorescent tube. The pink waveform is the tube current while the purple waveform is the product of the tube voltage and current (power is 36W).

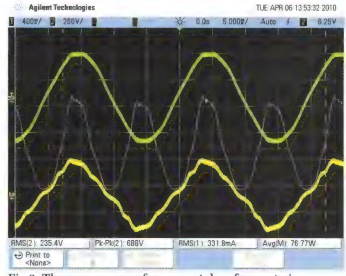


Fig.2: These scope waveforms are taken from a twin-36W electronic ballast luminaire. The green trace is the incoming 230VAC waveform while the yellow trace shows the overall current. The purple waveform is the product of the voltage and current (power is 77W).

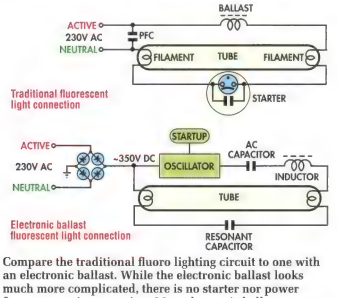
That's towards the low end of the relevant Australian standard for office lighting (see separate panel: "What is the *correct* office light level") but I found that it was more than enough for normal work. In fact, I found anything much greater than about 300 lux started to become a problem, especially when trying to read glossy or even semi-gloss (ie, coated) magazine pages.

Pull out a tube!

All of the tests so far had involved twin-36W luminaires using conventional ferromagnetic ballasts and starters. And by removing one lamp from each fitting, we obtained a reduction in power of just under 50%.

Why not exactly 50%? The discrepancy is due to the 8µF 250VAC power factor correction capacitor in the luminaires. This has been selected to correct the power factor of two ballasts in the luminaire and it over-compensates when just one ballast (ie, one tube) is in use.

So in practical terms, we were able to reduce the power consumption of a twin 36W luminaire from around 90W to about 48W. The extra wattage compared with the power rating of the fluorescent tubes themselves (37W) is the amount of power wasted in the ferromagnetic ballasts.



Compare the traditional fluoro lighting circuit to one with an electronic ballast. While the electronic ballast looks much more complicated, there is no starter nor power factor correction capacitor. Most electronic ballasts power two 36W tubes (not one as shown here for simplicity). The tube filaments in an electronic ballast circuit are essentially ignored – there is certainly no need to heat them.

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Small office tests

In order to do a more controlled test, we decided to repeat the procedure in a separate office measuring 3.2 metres square (10.24 square metres), occupied by one Ross Tester.

It was lit by two twin-36W luminaires, although one tube in one fitting was missing. The initial light measurement was 270 lux and that rose to 340 lux, with four tubes fitted. Removing the rather dusty prismatic diffusers increased the reading to 350 lux.

Cutting to the chase, we removed the tubes from both fittings and fitted two NEC 37W quad phosphor 5000°K tubes to the luminaire immediately above the centrally placed desk. Now, with the lux meter sitting on the desk (as it was for the previous measurements), the reading jumped to 380 lux and then increased again to 420 lux with the prismatic diffuser cleaned and replaced. (Obviously the diffuser concentrates the light downward, hence the increase in brightness with it fitted).

Pretty good eh?

So, we have reduced lighting energy use in that small office from around 180W (with four tubes fitted) to 90 watts. But wait, there's more!

Electronic ballasts

While simply replacing tubes with the new quad phosphor units makes a lot of sense, it is not without problems.

First, starters, starter sockets and tombstones (the sockets in which the tubes sit) can become quite brittle with age and

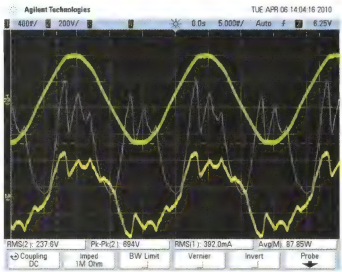


Fig.3: by contrast, these waveforms are taken from a twin-36W conventional ballast luminaire. Notice that the purple power waveform is 87.85W, substantially higher than for the electronic ballast fitting.

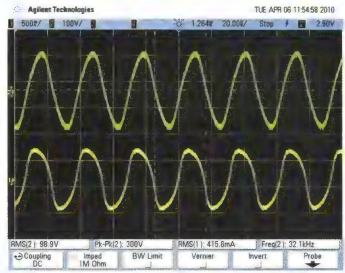


Fig.4: the high frequency operation of a single tube in a twin-36W electronic ballasted fitting. It is being driven at 32kHz and gives about 9 or 10% more light output.

the mere act of changing tubes or starters can fracture them.

Then what do you do? If you're doing the changeover yourself in a small office, you might consider replacing dud sockets but it is a time-consuming and dirty job. It would certainly not be practical to have the job done by an electrician, as the labour costs would be high. In any case, suitable tombstone sockets may not be readily available (most fittings these days have snap-in sockets made to fit a specific punch-out).

In this case, you would simply replace the entire luminaire with one using an electronic ballast. These are now readily available at lighting wholesalers and are actually cheaper than the identical fittings with conventional ballasts.

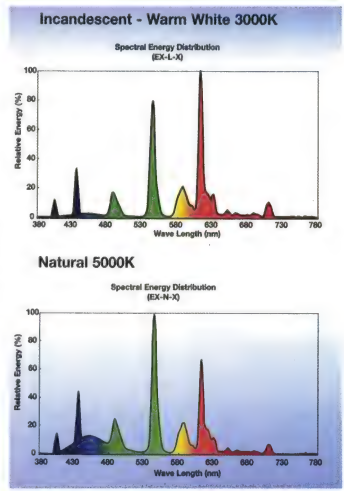
The catch is that typical twin-36W luminaires usually have one electronic ballast driving two tubes; you cannot operate them with a single tube. And while it is possible to purchase luminaires with a ballast driving a single tube, they will not necessarily fit into the same space occupied by the twin-36W fitting.

But depending on the spacing of the twin-36W luminaires, it may be possible to fit electronic ballast versions and leave some fittings without any tubes. And that is what we did in the small office just discussed. We substituted a twin 36W luminaire with electronic ballast for the two conventional luminaires.

This leads to two further benefits. First, electronic ballast luminaires are far more efficient than those with conventional ballasts. Compared with the 90 or so watts drawn by a twin-36W conventional ballast version, the electronic version only draws 77 watts, a power saving of 15%. Better still, the light output can be expected to increase by about 9%.

Now why is that?

It's not magic. In a conventional ballasted fluorescent light fitting, the light output from the tube varies more or less sinusoidally at 100Hz, ie, double the 50Hz mains supply



These two graphs show the spectra of warm white (3000°K) versus "natural" 5000°K tubes. Notice that there is far more output at the "blue" end of the spectrum for the 5000°K tubes. (Courtesy Nelson Lamps Australia, distributors of NEC fluorescent tubes.)

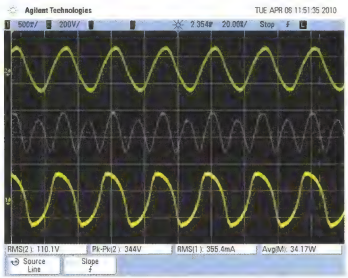


Fig.5: this is the same test set-up as in Fig.4 but the scope is set to display the power waveform (purple trace) and shows a result of 34W. Depending on how this measurement is taken, it can vary from around 40W to less than 25W but the averaged long-term value is around 34W.

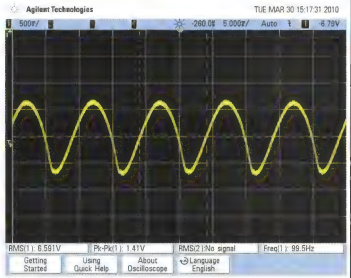


Fig.6: this waveform shows the light output from a ballasted fluorescent tube, measured with a phototransistor. Notice that the light output is modulated at 100Hz, ie, with peaks corresponding to twice the 50Hz mains supply

frequency. In effect, the lamp is extinguished 100 times a second but the persistence of the tube phosphor smooths this out so that flicker is normally not noticeable.

By contrast, electronic ballasts run the tubes at much higher frequencies. In the case of the units we purchased, the drive frequency is around 32kHz.

In effect, there is less variation in the UV radiation from the mercury vapour in the tube and the phosphors provide further smoothing. We have included some scope grabs of the typical light variation from a conventional ballast fitting and one fitted with electronic ballast.

Interestingly, the light from the electronic luminaire still exhibits 100Hz modulation, overlaid with a much smaller modulation at 32kHz. However, the 100Hz modulation is about half that from the conventional ballast fitting.

So what happened is that when we changed to an electronic ballast luminaire in Ross Tester's office, the light reading increased to around 460 lux. By this stage Ross was asking whether he should be issued with sunglasses and skin cream for protection from UV exposure. It certainly is quite bright . . . but he got short shrift!

Electronic ballasts have other side benefits as well. First, there is no apparent light flicker.

Second, there is no audible hum or buzz which can be a problem with conventional ballasts. Third, there is none of that flick, flick, flickity flick when the lights are first turned on.

Finally, because no starters are involved, they don't need to be replaced when they fail (another saving!) and the ends of the tubes do not blacken so much as they age.

However, there are two minor drawbacks with using electronic ballasts. The first is that if the ambient temperature is less than 5°C, the tubes may not start reliably. This is a problem with all fluorescent lights but apparently it is more pronounced in those fittings which have electronic ballasts.

We have not tested this aspect – not only was it a balmy autumn (albeit damp) when we did our tests but the last time it regularly got to less than 5° here on the northern beaches of Sydney, dinosaurs were dropping dead.

Secondly, the twin-36W electronic ballast luminaire we tested produced significantly more interference to AM radio reception than a conventional ballasted fitting. We have included some scope grabs of the interference waveform from each type.

Even in this un-retouched photo of a twin fluoro fitting (which really doesn't do it justice!) you can readily see the light level difference between a 4200°K tri-phosphor (the tube on the bottom) and 5000°K quad-phosphor (on top). While the "warmer" colour temperature of the tri-phosphor accounts for some of this difference, the quad phosphor is much brighter.

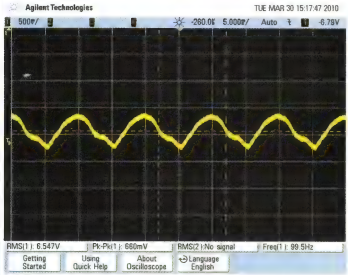


Fig.7: this shows the light output from a fluorescent tube driven by an electronic ballast. Notice that the light output is actually higher but still modulated at 100Hz and by about 50% less. It also shows very slight modulation at 32kHz.

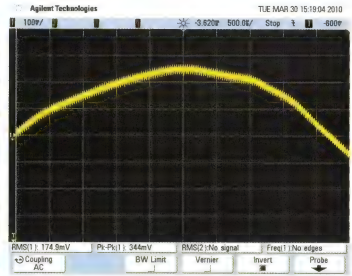


Fig.8: this is the same waveform as in Fig.7 but with the scope settings changed to highlight the slight 32kHz modulation in the light output.

This could be a problem if you live in an area where AM reception is weak. But you'd probably already know this from interference from all your switchmode supplies!

Colour temperature

All our tests involved fluorescent tubes with a 5000°K colour temperature. They are noticeably brighter than Cool White 4200°K or other colour ratings. Their colour rendering is also quite reasonable with a Colour Rendering Index (CRI) of 84.

In practice, we found the NEC quad-phosphor Natural 5000°K tubes to be far superior to all other tubes, especially those labelled Warm White (3000°K).

Total power savings

In all, we replaced the two old tubes in each of 17 twin-36W luminaires with 17 NEC quad phosphor tubes. The total power saving (including the changeover to one electronic ballast twin-36W fitting) is around 730 watts.

Considering that these lights are typically on for 10 hours a day or around 2500 hours per annum, that means a saving of 1825kWh per annum. At the current tariff of 22c/kWh, that is a saving of over $400.

Neglecting labour cost for the exercise (because we would have had to replace many tubes anyway), that means the payback is less than one year. And the whole office is considerably brighter into the bargain.

By the way, we have been told by a distributor that the wholesale cost of NEC quad-phosphor fluorescent tubes is now actually *less* than their equivalent tri-phosphor tubes. So retail prices of quad-phosphor tubes should be coming down quite soon.

T8 versus T5 tubes

In none of this discussion have we mentioned T5 fluorescent tubes. Hmm, what's this about T8 and T5 tubes? Simply put, this nomenclature refers to the diameter of the tubes in eighths of an inch.

What is the *correct* office light level?

Insufficient light level in the workplace can cause eye strain, headaches and possibly induces migraine. And accidents occur more often when workers have difficulty seeing at less than optimum levels.

By the same token, excess light levels are also not good for the health and safety of workers. Again, headaches, fatigue, stress and possibly migraines have been blamed on excessive light levels in the office. Try reading a newspaper in direct sunlight, for example and you will agree it's not comfortable!

Even if there were no ill-effects from excess light levels in the office, they of course waste a lot of energy. And that's becoming even more important as electricity costs keep rising.

As you might expect, there is an Australian standard covering the amount of light required in an office.

AS1680.2.2 suggests that for ordinary office tasks, the lighting level should be in the range of 300-400 lux at desk (task) level and 160 lux as a background.

The simple action of moving a desk (to accommodate other furniture or fittings, for example) may mean that what was acceptable light level is no longer enough. Or vice versa of course.

Some applications will require stronger lighting – intensive manual graphic arts (ie, not on computer screen) such as drafting, illustrating, etc, may require illumination of up to 750 lux. Tasks involving constant reading, especially from small type, working with material that is not sharp (eg, poor photocopies) and similar has a suggested minimum of 600 lux.

Older workers, too, usually require stronger lighting (ie more illumination) than younger workers.

And speaking of computer monitors, every graphic artist will attest that too much illumination (whether from lighting or natural sources) on a monitor can drastically alter results, especially where colour rendition and lightness/darkness in image manipulation is concerned.

Making the measurements

Quite a few different measurements were made in preparing this article. First, we measured the light output in the offices with a Digitech light meter available from Jaycar (Cat QM-1587). This will measure in lux or foot-candles. In parallel with that, we used Digitech (Jaycar QM-1580) digital multimeter which includes ranges for measuring lux.

The various oscilloscope measurements posed a number of problems. First, most oscilloscopes can only handle limited input voltages and we wanted to measure the 230VAC mains voltage waveforms. These will overload any normal scope with a maximum input range of 5V/div when used with a 10:1 divider probe. Our solution is to use our 100:1 divider probe which is a PMK PHV621, made in Germany.

When plugged into an oscilloscope with probe sensing, the maximum input range becomes 500V/div. For current and most of the scope measurements in this article we used a setting of 100V/div. It was used to monitor the incoming 230VAC 50Hz sine waveform.

We also wanted to monitor the voltage across the fluorescent tubes themselves in both the conventional ballast and electronic ballast luminaires. This presents several problems. First, we need to measure the current in the Active-Neutral circuit and this really needs to be done with an active current probe which can be isolated from the mains circuit. To that end, we used an Agilent 1147A current probe which has a bandwidth from DC to 50MHz and a continuous current rating of 15A (50A peak). Conventional current probes for oscilloscopes simply do not have sufficient bandwidth to measure the fluorescent tube operating frequencies which can range well above 35kHz in luminaires which have electronic ballasts.

The Agilent 1147A current probe is a hybrid unit combining a Hall Effect sensor for DC measurements and a current transformer for AC measurements. Its output is 0.1V/A and if connected to an oscilloscope such as the Agilent 5000/6000/7000 series, it will be automatically sensed and the trace will show amps/div rather than volts/div.

A further complication arose because we wanted to measure and display the voltage waveform directly across the fluorescent tubes. This is difficult enough in a conventional ballasted fitting but is more complicated in fittings with electronic ballasts which operate two tubes from the one ballast. The solution is to use an active differential probe and in this case we used a Pintek DP-25. This can handle a maximum voltage of 1000V RMS on its differential inputs while the maximum voltage between each input and ground is 600V RMS, ie, more than adequate to handle the voltages involved when making scope measurements on the 230VAC mains supply. It has three ranges: x 20, x50 and x200.

For further information on the three items described above, the high voltage probe, current probe and active differential probe can be obtained from Trio-Smartcal, 3 Byfield Street, North Ryde, NSW 2113. Phone 1300 134 091. www.triosmartcal.com.au

Other measurements

We also measured power consumption of the various luminaire fittings and this was done with our own Appliance Energy Meter which was featured as a constructional project in the July & August 2004 issues. In addition, we compared the level and modulation of the light output of the conventional ballast and electronic ballast fittings. This was done using a standard phototransistor with a 10kΩ collector load resistor. These scope waveforms (Figs. 6, 7 & 8) are measured with the same reference level. We confirmed that not only is the light output from the electronic ballast fitting higher than the conventional ballast fitting but that the 100Hz modulation was about half.

Finally, as a crude measurement of electromagnetic interference from the two types of luminaire, we used a standard portable AM radio while the interference waveforms were taken from a small coil of wire in close proximity to the respective fluorescent tubes.

Fig.9: the 50Hz interference signal radiated from a fluorescent tube with conventional ballast. It will be heard as a characteristic loud buzz in an AM radio.

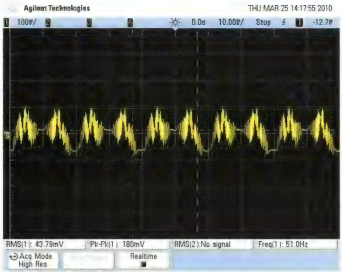


Fig.10: the 50Hz interference signal radiated from a fluorescent tube with electronic ballast. It will produce a lot more interference to AM radio reception.

Hence, a T8 tube is nominally eight eighths or one inch in diameter and a T5 tube is 5/8-inch. The newer T5 tubes are claimed to be more efficient than T8 tubes and can only be run with electronic ballasts. However, if T8 tubes are similarly run with electronic ballasts, there is no difference in efficiency in terms of lumens/watt.

In any case, T5 luminaires and T5 tubes are currently a great deal more expensive than T8s. There is no point in changing over.

And why not LED replacements?

Some readers may wonder why we have not considered LED replacements for fluorescent tubes. After all, they are available overseas, even in a "drop-in" package; that is, the same size and shape as a conventional fluoro tube and capable of being driven in the same fittings.

The simple answer is that while the very best of them can only just match the efficiency of NEC quad-phosphor tubes (around 100lm/W), they are extremely expensive.

In the next few years that is bound to change.

The next step?

The next step in the power saving saga is to eliminate those wasteful halogen downlights in our office. We will bring you more in due course. SC

Here's what to look for on the fluorescent tubes themselves. Top is the 3000°K NEC tri-phosphor, while below is the brighter 5000°K NEC quad-phosphor. Both are rated at 37W and both are "T8", or one-inch diameter, tubes. Note the absence of the "HG" (mercury) marking on the quad phosphor.

Simple steps to start saving

(1) **At the very least**, remove and wash the diffuser and while it is out, wipe over both the fluorescent tubes and the inside of the fitting with a damp cloth. This won't save you any power but you won't be wasting any of the light output from what you've got.

(2) **Better still**, do No.1 but at the same time, replace the old tubes with tri-phosphor tubes. Again, you'll get even more light output for the same power.

(3) **Much better again**, replace the old tubes with quad-phosphor tubes. You may well find (as we did) that you only need one quad-phosphor in each fitting. That's an immediate power saving of 50% or more AND more light output than the pair of old tubes.

(4) **Best**, replace the whole light fitting (usually called a "troffer" in the trade) with one fitted with an electronic ballast AND a quad-phosphor tube. You can normally do this quite legally yourself because these days, the vast majority of commercial/industrial fluorescent lighting fixtures are fitted with a standard 3-pin power plug which mates with a 3-pin socket on the lighting circuit inside the false ceiling.

You might well ask "why not keep the existing fitting but simply replace the ballast with an electronic type?" We asked the same question of our wholesalers and found that the electronic ballast cost almost as much as a complete fitting (within a couple of dollars!) . . . and then you have to pay an electrician to replace it because that's something you cannot legally do yourself! So it is economically unviable.

A look at the TDA7377 quad 12V amplifier IC

The TDA7377 IC from ST Microelectronics is the main component of this month's 12V Mini Stereo Amplifier. It's not a new chip – they've been making them since at least 1998 – but it is the first time we've used it so it deserves some elaboration. It comes in a 15-pin "Multiwatt" package similar to TO-218 and is available in both horizontal and vertical mounting packages.

By NICHOLAS VINEN

THIS IC is designed for use in car stereo systems and can provide four single-ended channels, two bridged channels or a combination of two single-ended and one bridged channel. Maximum power depends on speaker impedance, supply voltage and channel configuration but the most useful figures are 4 x 10W into 2Ω, 4 x 6W into 4Ω and 2 x 20W into 4Ω.

Noise performance and channel separation are also quite good. The S/N ratio is typically close to -100dB and channel separation is generally at least 60dB at 10kHz. This is surprisingly good when you consider that all four power amplifiers share the same package and power supply pins.

The best features of this IC are its low distortion (down to 0.02% or less) and high power. The most basic circuit for driving two speakers requires just the IC, five small capacitors, one large capacitor (for supply bypassing) and one resistor. It doesn't get much easier than that!

Because there are no external gain-setting resistors, this means that the gain is internally fixed. This is both a blessing and a drawback – while it reduces the component count, we can't adjust the gain to our liking. However, their choice of 20dB gain per circuit is reasonable.

This actually results in 26dB of gain in bridge mode. The reason is that in bridge mode, twice the voltage is placed across the speaker as in single-ended mode. This equates to +6dB of additional gain.

As is typical for integrated amplifiers, there is a standby pin which allows the amplifiers to be electronically shut down when not in use. In this condition, the quiescent current is around 1μA. The standby pin also prevents clicks and pops during turn-on and turn-off, because it either mutes or un-mutes the signal paths when it is switched.

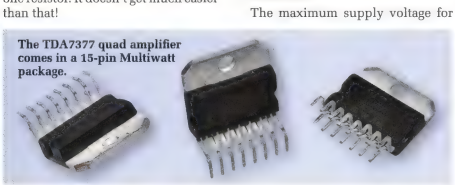
Protection

The maximum supply voltage for the IC is 18V but it can withstand up to 28V when it is not operating and spikes of up to 50V for no longer than 50ms. Each channel can deliver up to 3.5A continuously (4.5A peak) and the maximum dissipation is 36W.

In fact, not only can the IC handle voltage spikes but it is virtually indestructible if kept within its limits. Output shorts, excessive current, overheating, inductive and capacitative loads, short-term open-circuit ground wiring, reversed battery – none of these will destroy it, thanks to internal protection circuitry.

The thermal limiting isn't just a simple cut-out which disables the amplifier either. The current limiting gradually increases with die temperature, so that at first it creates only mild output distortion while reducing the dissipation in an attempt to prevent further temperature increases.

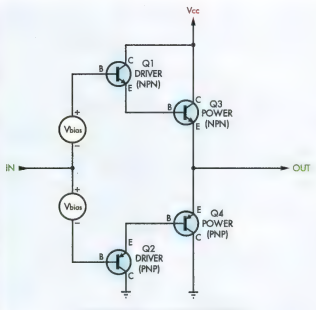
If driven hard enough it will eventually lead to heavy clipping but this is a nice feature. The amplifier can still be used if it is approaching its junction limits and if the overload is temporary or marginal, the listener may not even notice.



The TDA7377 quad amplifier comes in a 15-pin Multiwatt package.

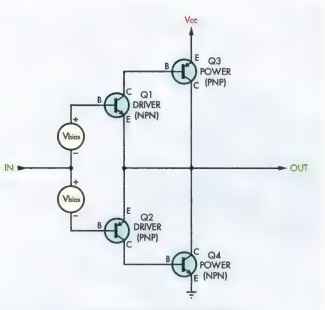
Implementation

While implementing an amplifier with this IC is simple, there are a few tricks. Firstly, because it is optimised for bridge configurations, two of the amplifier circuits are inverting and two are not. This means that if you want



DARLINGTON OUTPUT STAGE

Fig.1: the traditional amplifier output stage consists of two complementary Darlington transistor pairs in emitter-follower configuration.



COMPOUND OUTPUT STAGE

Fig.2: the compound pair output stage configuration. It's advantage is that is has a greater voltage swing than the Darlington arrangement shown in Fig.1.

to use them as four separate channels, you need to reverse the speaker wires for the two which are being driven from the inverting amplifiers. That way, all four outputs are kept in phase.

Care must also be exercised to keep the power ground and signal ground lines separate, except where they meet at the star-earth point.

The purpose of the "SVR" capacitor is not explained in the data sheet but "SVR" stands for "Supply Voltage Rejection". This capacitor filters the internal half supply in the IC, so that supply variations do not couple into the signal paths. This is why it must be connected to the signal ground. If connected correctly, the supply voltage rejection figure is in excess of 50dB at 300Hz.

One feature that we did not use in our 12V Minis Stereo Amplifier design is the diagnostic pin. It is an open collector output which is turned on during clipping, thermal limiting or an output short circuit. It can be used to light an indicator lamp or drive some kind of fault display. Alternatively, a circuit can be added to engage dynamic range compression if high volume is causing the outputs to clip.

Clipping can be distinguished from other faults by noting the duration of the diagnostic output pulses or by measuring the average current sunk by that pin. Shorter pulses indicate clipping, longer pulses are caused by short circuits or thermal limiting.

Output stage

The most interesting feature of the IC is its output stage. It achieves a true rail-to-rail swing (minus transistor saturation at high currents) with no possibility of oscillation and yet doesn't introduce high levels of distortion. Let's see how they did it.

Integrated amplifiers like the TDA-7377 are sometimes referred to as "power op amps". The main difference between an amplifier IC and an op amp is the amount of current they can deliver. The TDA7377 can be likened to a high power rail-to-rail op amp.

There are two different types of rail-to-rail op amps. The first is usually referred to as just "rail-to-rail" or "RR" and this means that the output voltage swing goes very close to both the positive and negative supply. How close depends on the load – at light loads (ie, high impedances) it will swing very close indeed, often to within a few millivolts. At heavier loads (ie, low impedances) it may only go within a half a volt or so, due to resistance effects in the output transistors.

The second type is usually more expensive and is called "rail-to-rail input/output" or "RRIO". This means that not only can the output voltage go close to both supply rails but the input common mode voltage range also extends to, or beyond, both rails.

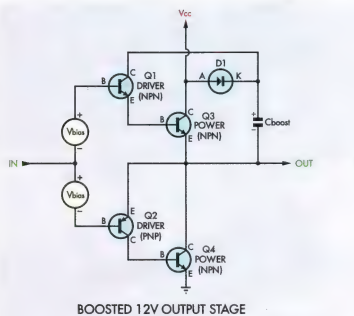
Since in this case we are dealing with a power amplifier that has a large fixed voltage gain, the inputs do not need to extend to the rails. With a gain of 20dB (a factor of 10), a 1.2V peak-to-peak sinewave input signal (424mV RMS) is enough to drive the outputs to a full 12V swing. So RRIO is not really necessary for an AC signal when there is enough voltage gain.

Traditional output architectures

A traditional amplifier output stage consists of two complementary Darlington transistor pairs in an emitter-follower configuration – see Fig.1. This is very simplified but shows the most important components. This output stage can only swing to within about 1.4V of each supply rail, because of the two base-emitter drops in each transistor pair. In other words, if V_{CC} is 12V and the base of Q1 is at 12V, the emitter of Q3 will be around 10.6V.

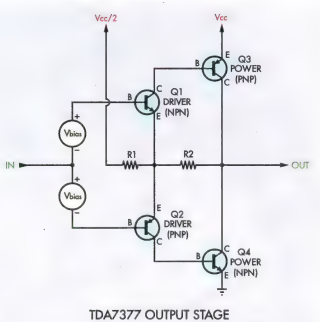
If we used this architecture for a 12V amplifier, the maximum output swing would be 9.2V peak-to-peak, resulting in a poor maximum power figure.

Fig.2 shows a similar but arguably superior configuration. The Darlington



BOOSTED 12V OUTPUT STAGE

Fig.3: the boosted "quasi-complementary" arrangement uses a "boost" capacitor to generate a voltage above V_{CC}. This is used to drive the upper half of the output stage and allows the output to swing all the way up to the positive rail, minus the collector-emitter drop of Q3.



TDA7377 OUTPUT STAGE

Fig.4: the output stage configuration of the TDA7377. It's similar to the compound pair arrangement of Fig.2 but includes local gain. Because the emitters of the driver transistors are no longer tied to the output, their base-emitter voltage no longer affects the output swing.

pairs have been replaced by compound pairs, also known as "Sziklai" pairs. Compound pairs only have a single base-emitter drop (in the drivers), so this improves the output swing to more like 10.6V peak-to-peak.

Some integrated amplifiers use both these concepts. By using a Darlington upper stage and a compound lower stage, both of the high current output devices are NPN transistors. Silicon NPN transistors are traditionally better than their PNP equivalents, although this is less true now than it once was.

Fig.3 illustrates this arrangement, which is known as a "quasi-complementary" output stage. It also adds a "boost" capacitor to generate a voltage above V_{CC}, which is used to drive the upper half of the output stage. This allows the output to swing all the way up to the positive rail, minus the collector-emitter drop of Q3, which depends on the transistor size and output current.

Charge pump

The circuit works by using the output of the amplifier as a charge pump. When the output swings low, the boost capacitor (Cboost) is charged up to nearly the full V_{CC} voltage via diode D1 – let's say to 10V. Then when the output swings high again, D1 prevents the capacitor from immediately discharging.

Because the voltage across the capacitor stays the same, when the output swings up, Q1's collector does too. It goes well above V_{CC} if the output swing is large enough – in this example, nearly 22V. This higher voltage means that both Q1 and Q3 can be turned fully on, even when the output is near V_{CC}.

During the time when the output is above about 9.5V, the boost capacitor discharges through Q1 and then Q3's base. It must be large enough so that at 20Hz it won't discharge below 1.4V before the output swings back below 9.5V and it is recharged.

This design has an output swing of 11.3V – just one diode drop away from being rail-to-rail. It's possible to add a second boost capacitor for the negative rail but there are other techniques which provide a full rail-to-rail swing with a single boost capacitor. They usually involve making the lower output pair into an NPN Darlington and adding a more complex driving arrangement.

How the TDA7377 does it

Fig.4 is derived from the diagram in the ST Microelectronics data sheet and shows the output architecture used. It's basically identical to Fig.2 (the compound pair stage) except that it also includes local gain. The main advantage is that because the emitters of the driver transistors are no longer tied to the output, their base-emitter voltages no longer affect the output swing.

Consider the case where the gain set by the resistors is 10 (as in the IC) and the output is at +11V. The junction of R1 and R2 will be at 6 + (11-6)/10 or 6.5V. Thus, it's only necessary to drive the base of Q1 up to 6.5V + 0.7V or around 7.2V in order to turn on Q1 and thus also turn on Q3.

So with this arrangement there is no problem turning on Q3 until the point where the output rises to V_{CC}.

Now we can take account of the output transistor saturation and calculate just how large the output swing will be. All the previously described output stages will suffer from transistor saturation, as this depends almost entirely on the output transistors themselves.

According to the data sheet, the equivalent resistance in the collector-emitter junctions of Q3 and Q4 is 0.3Ω. We can calculate that with a 4Ω resistive load and a 14.4V supply, there will be a maximum of 14.4 / 2 / 4 = 1.8A flowing through the power transistor. This will result in a collector-emitter

drop of 0.3 x 1.8 = 0.54V, meaning that the output swing under such conditions will be 13.32V peak-to-peak – not bad at all.

Amplifier stability

Another area where the TDA7377 has improved on previous designs is with its stability. Virtually all amplifiers with feedback systems – and this includes op amps – can suffer from instability. This is because there is always a signal delay within the amplifier. A change in the input signal does not immediately result in a change in the output.

The signal is delayed by various capacitance effects inside the amplifier, mainly within its transistors. This delay, in combination with the negative feedback used to set the gain and eliminate distortion, can result in oscillation. The amplifier behaves a bit like a fish-tailing vehicle – each corrective input has a delayed effect and leads to wild over-correction. As a result, the corrections need to be damped in order to prevent this problem.

In an op amp, this is usually done with an internal compensation capacitor, although some (such as the NE5534) require external compensation. If an IC lacks compensation pins, a small capacitor between the inverting input and output, or between the two inputs, can do the job.

However they are attached, these capacitors are configured to reduce the gain at high frequencies, where the signal delay is large compared to the waveform period. As long as the gain is below unity before the phase shift exceeds 180°, the amplifier is usually stable. The difference between the phase shift at unity gain and 180° is known as the "phase margin" and indicates how much extra phase shift can be added before oscillation will occur.

For power amplifiers, stability is achieved differently. A Zobel network (also known as a "Boucherot cell") is typically added to the output. This consists of a resistor and capacitor in series connected between the output and ground. Sometimes an RLC filter is also added, to isolate the amplifier from the capacitance of the circuitry it is driving.

The Zobel network has the effect of being a frequency-dependent load. At low frequencies, the capacitor's impedance is high, so it has no effect. However, as frequency climbs, the impedance drops to a value limited by the resistor and the loading starts to become significant.

As a result, the output stage needs more current to create the same magnitude of voltage swing, reducing the gain. Thus, high-frequency oscillations are damped.

We've already seen how the TDA-7377 avoids the need for an external boost capacitor or for gain-setting resistors. In addition, the boffins at ST Microelectronics have found a way to avoid the requirement for a Zobel network.

How did they achieve unconditional stability? According to the data sheet, it is partially due to the way the gain is incorporated in the output stage, and partly by way of careful control over the H_{FE} (ie, current gain) of the output transistors. They have adjusted this gain (by changing the transistor geometry) so that it is high enough to provide sufficient open loop gain for decent sound quality but low enough that runs out of steam at high frequencies before oscillation begins. SC

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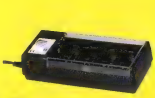

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Need lighting away from a power source? Try this one: it's ideal for your garden, shed or even a camp site. With a 5W solar panel, a 12V SLA battery and a smart controller, it has 3-stage charging for the battery and Maximum Power Point Tracking (MPPT) for the solar panel.

Part 1 – By JOHN CLARKE

...stage charging...

Features

- 12V SLA battery operation
- Ideal for LED lighting
- Constant current LED driver option
- PIR, switch or ambient light turn-on
- Lamp timer included
- 5W solar panel with 3-stage battery charging

No, it's not the old Irish joke about the bloke who invented the solar-powered torch!

Solar-powered lighting is ideal where it is impractical or unsafe to install mains-powered lighting. It can be installed just about anywhere and best of all, running costs are zero because it uses energy from the sun.

In its simplest form, solar powered lighting comprises a solar panel, a battery and a lamp that can be switched on and off. But you do need to ensure that the battery is not over-charged during the day or over-discharged at night; so you need some sort of charge and discharge controller.

Fig.1 shows the arrangement of our Solar Lighting Controller. The solar panel, the battery and the lamps connect to the Controller, allowing full management of charging and lighting. Additional inputs to the Controller include a light sensor to monitor the ambient light, a Passive Infra- Red (PIR) detector and a timer.

For use in garden lighting, the light sensor allows the lights to switch on at dusk and they can remain lit for a preset period of up to eight hours, as set by the timer. Alternatively, you may wish to have the lights lit for the entire night and to switch off automatically at sunrise (subject, of course, to sufficient battery charge).

For security or pathway lighting, the lights can be set to switch on after dusk but only when someone approaches the area.

In this case, a PIR movement detector switches on the lights while the timer switches off the lights after a predetermined period, typically about one to two minutes but settable up to the 8-hour timer limit.

For shed lighting, you may opt to switch the lights on and off using a remote pushbutton switch. They can remain on until they are switched off again or they can switch automatically after a preset period, or at sunrise.

Normally the Controller would be set so that the lights can only come on when it is dark. However, you might want the lights on during day in a shed and this is also possible.

Table 1 shows a summary of all the lighting options which are selected using jumper links. We'll look at these various options later.

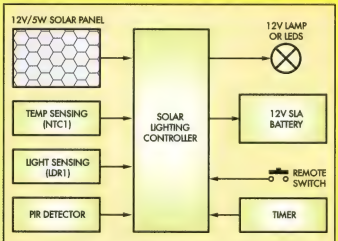


Fig.1: this shows the arrangement of our Solar Lighting Controller. The solar panel, SLA battery and the lamps connect to the Controller. Optional inputs to the controller include a light sensor to monitor the ambient light, a PIR detector and a timer.

Types of lighting

The Solar Lighting Controller can power 12V compact fluorescent lamps (CFL), halogen lamps and 12V LED lighting. In addition, the Controller can directly drive LEDs using a constant current driver. Best efficiency is obtained with three 1W or 3W white LEDs in series.

The actual total wattage of the lights depends on the application. We recommend that the Solar Lighting Controller be used with up to 10W of lighting when the lights are used for a maximum of 2.5 hours each day.

Lower wattage lighting can give longer lighting periods. For example, 3W of lighting can be used for around seven hours per day.

The restriction on the lighting wattage and usage depends mainly upon the solar panels and their ability to recharge the battery each day. The specified 5W solar panel is ideally suited for recharging a partially discharged 3.3AH battery during the day, assuming at least six hours of winter sunlight is available.

Summer time will obviously provide more hours of sunlight for charging but then there will usually be less need to use the lights because of the reduced night period.

Lead-acid batteries (***including*** SLAs, despite popular belief to the contrary) will be seriously damaged or rendered inoperative if they are fully discharged and/or left in a discharged state. Hence, we have included low battery detection. Should the battery become discharged below 11V, the lights will switch off.

Low standby current

Standby current drain of the Solar Lighting Controller is low to conserve battery power and this has been achieved without using special components, apart from the PIR sensor. This sensor is designed for use with battery equipment where current drain is a major consideration, and is available from Altronics (Cat SX5306). We measured current drain on our sample unit at 73μA from a 12V supply. This

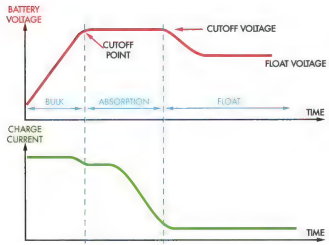


Fig.2: this shows the three charge stages. First is the initial bulk charge until the battery reaches the cutoff voltage. Then the absorption stage to fully charge the battery and then the float charge at a lower voltage to maintain charge.

rises to 1.3mA with movement detection, due to lighting of the internal detection indicator LED. Overall quiescent current for the Controller is 2.8mA.

3-stage charging

The Controller charges the SLA battery from the solar panel in three stages, as shown in Fig.2. First is the "bulk charge", applied when the battery voltage drops below 12.45V. This charge cycle applies maximum power from the solar panel until the battery voltage reaches cut-off at 14.4V, @ 20°C.

Next is the "absorption" phase where the battery is maintained at the cut-off voltage for one hour, to ensure the battery becomes fully charged. After that, the battery is maintained on "float" charge at 13.5V.

The cut-off voltage for the bulk charge and the float voltage is reduced for temperatures above 20°C, in accordance with the battery manufacturers' charging specifications. Typically, this is 19mV per °C for a 12V battery. So at 30°C, the voltages are reduced by 190mV, ie, 14.21V and 13.31V respectively.

Ambient temperature is measured using a NTC (negative temperature coefficient) thermistor located within the Controller. The monitored ambient temperature should be similar to that of the battery, provided it is located in the same area as the Controller. The thermistor can also be located adjacent to the battery, if required for a more accurate temperature measurement of the battery.

No charging will occur if the thermistor is shorted or if it is not connected. This feature is useful when the thermistor is remotely located where the wiring could become shorted or broken. A LED indicator flashes momentarily once every two seconds when the thermistor is open circuit and momentarily once every one second when shorted.

Charging is also indicated using the same LED indicator. Bulk charge is indicated when the LED is on continuously while it flashes on for 0.5s and 0.5s off for the absorption and one second on, one second off during float.

A battery that has been discharged below 10.5V will be charged using short burst of current until it reaches 10.5V whereupon the main charge will begin. This initial charging will be indicated by a short flash of the charge LED every four seconds.

MPPT & charge optimisation

The Controller optimises the available charge from the solar panel. As shown in Fig.3, a typical solar panel provides an output that follows the curve that ranges from maximum current when the output is shorted (I_{SC}) to maximum voltage when the output is open circuit (V_{OC}).

For the Altronics N0005 panel featured in this article, I_{SC} is 320mA and V_{OC} is 21.6V. Maximum power is 5.05W at 290mA and 17.4V.

When we consider the power delivered to the battery, the story becomes more interesting. If we were to connect the solar panel directly to the battery, the charge current would be about 320mA at 12V (3.84W) and about 300mA at 14.4V (4.32W). Both these values are less than the 5.05W available from the solar panel at 17.4V.

The solar panel operates at peak efficiency when it is delivering maximum power. And that is where the Maximum Power Point Tracking (MPPT) aspect of the controller comes into play.

It is essentially a switchmode step-down power converter, which couples the available power from the solar panel to the battery with minimal power loss. At the same time, it provides 3-stage charging to the battery.

Fig.4. shows how this takes place. Current from the solar panel flows through diode D1 via Q1. When Q1 is on, current (i1) flows through inductor L1 into the 470µF capacitor and the battery. The inductor charges (ie, current rises to its maximum value) and after a short period, Q1 is switched off and the stored charge in L1 maintains current flow (i2) via diode D2.

The ratio of the on to off period (duty cycle) for Q1 is controlled so that the solar panel delivers its maximum power. The solar panel is not required to supply the peak current into the inductor as this is drawn from the 470µF reservoir capacitor, C1. Similarly, capacitor C2 acts as a reservoir to charge the battery when current is not flowing through the inductor. Incidentally, these capacitors are low ESR (effective series resistance) types, suited to the switching frequency of 31.24kHz.

The voltage from the solar panel is monitored by op amp IC2a while the current is monitored by measuring the voltage across a 0.1Ω resistor. This voltage is multiplied by –50 in op amp IC2b. Both op amps feed their signals

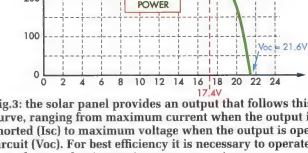


Fig.3: the solar panel provides an output that follows this curve, ranging from maximum current when the output is shorted (Isc) to maximum voltage when the output is open circuit (Voc). For best efficiency it is necessary to operate the solar panel at its maximum power point.

Here's the controller mounted inside its box. It snaps into place on the integral PC board supports. The cable glands on the left side make it fairly water-resistant but this box is definitely not waterproof!

to microcontroller IC1 which controls the whole circuit.

Circuit details

The full circuit for the Solar Lighting Controller is shown in Fig.5 and is based around a PIC16F88 microcontroller, IC1. It monitors IC2, the PIR sensor, switch S1, light dependent resistor LDR1 (for day/night sensing), the NTC thermistor and also controls lamp operation via Mosfet Q4.

For PIR operation using the Altronics SX5306 PIR detector, output from the PIR is normally at 0V but when it detects movement, the trigger output goes high to 4.5V. Output impedance of this PIR is high, at about 700kΩ, so it cannot provide much current before the voltage drops significantly. Hence, the input loading for this sensor signal is 10MΩ.

Note that resistor R2 is not used with the SX5306 PIR sensor. R2 is included if a standard PIR detector is used. Many standard PIR detectors include a relay with normally-closed contact that opens when movement is detected. With R2 included this provides a pull-up to 5V when the contact opens.

A 12V power supply for either type of PIR detector is included.

A pushbutton switch (S1) is monitored by the RB1

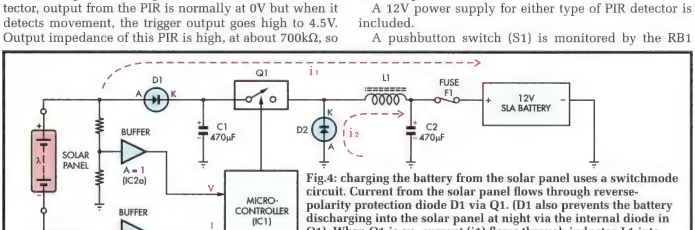


Fig.4: charging the battery from the solar panel uses a switchmode circuit. Current from the solar panel flows through reverse-polarity protection diode D1 via Q1. (D1 also prevents the battery discharging into the solar panel at night via the internal diode in Q1). When Q1 is on, current (i1) flows through inductor L1 into the 470µF capacitor and the battery. The inductor charges (ie, current rises to its maximum value) and after a short period, Q1 is switched off and the stored charge in L1 maintains current flow (i2) via diode D2.

input, normally held high at 5V with a 10kΩ pull-up resistor. Pressing the switch pulls the RB1 input low. S1 is included on the Controller PC board for test purposes but an external on/off (pushbutton) switch can be connected as well. The 100nF capacitor at RB1 prevents interference when long leads are used to an external switch.

Ambient light is monitored using the light dependent resistor (LDR1) at the AN5 analog input of IC1. The LDR forms a voltage divider with the series-connected 100kΩ resistor and VR5 connecting to the 5V supply. In normal daylight the LDR is a low resistance (about 10kΩ) but this rises to over 1MΩ in darkness. Therefore the voltage at the AN5 input will be relative to the ambient light. If the voltage across LDR1 is below 2.5V IC1 determines it is daylight; above 2.5V it reads it as dark.

This measurement is made when Mosfet Q6 is switched on, tying the lower end of the LDR close to 0V. VR5 allows threshold adjustment of the LDR sensitivity.

Link Options

There are three options available for turning on the LED/light: (1) only at night, (2) only in daylight or (3) either. The position of link LK1 selects the first two options, while the third option operates with the link in the "night" position but has the LDR left out of circuit.

The lamp can be switched on using the pushbutton switch S1 (internal or external), provided the ambient light level is correct according to the selection made with LK1.

When link LK2 is in the PIR position, the lamp can also be switched on when the PIR detects movement; again dependent on ambient light, according to the LK1 selection.

If PIR operation is selected with LK2 but the PIR detector is not connected to the circuit, then the lamp can only be switched on with S1.

If LK2 is set to the LDR position, the PIR does not switch on the lamp – the lamp is switched on at the change of ambient light, day to night or night to day (again, dependent on LK1).

Built-in timer

The lamp can also be switched off with a timer or ambient light. The various options are summarised in Table 1.

The lamp "on" period is adjustable using trimpot VR4, which connects between 5V and the drain of Q6. When Q6 is switched on, the trimpot is effectively connected across the 5V supply. The wiper voltage is monitored at the AN0 input of IC1.

We'll cover the procedure to set VR4 later.

Lamp driver

The Controller includes a constant current lamp driver which can power LEDs or standard 12V incandescent lamps. Current control is important for LEDs because with voltage control, small variations in the supply voltage can result in large changes in the current flow.

Mosfet Q4 and its associated components form an active current sink. Q4's transconductance is varied in response to the voltage developed across R1, which is proportional to the lamp current.

IC1's RB0 output switches on the lamp by applying

Specifications

Lamp driver	Constant current LED drive
Lamp current	Typically less than 350mA for 1W LEDs or less than 1A for 3W LEDs, or at 2A for 12V halogen and 12V LED lamps
Lamp timer	2s to 8h. See table 3.
LED driver	Up to 3 white LEDs in series. 1W or 3W types.
Lamp switch on	Via ambient light change, PIR sensor and switch
Lamp Switch off	Via ambient light change, timer or switch
Low battery lamp off voltage	11V
Quiescent current	2.8mA
Charging voltage	14.4V at 20°C for main bulk charge and absorption cut-off voltage. Float is 13.5V @ 20°C
Compensation	Adjustable from 0 to 50mV per °C, reducing charge voltage above 20°C and increasing below 20°C. No increase below 0°C.
Thermistor warning	Open or short circuit (Charge LED flashes 262ms every 2s for open circuit and 262ms every 1s for short circuit)
Low battery charge	At less than 10.5V charging via a 6.25% duty cycle charge burst (Charge indicator flashes 260ms each 4.2s)
Bulk charge initiation	When battery drops below 12.45V or the equivalent of 75% charge
Charge LED indicator	**Bulk charge:** Continuously lit. **Absorption:** flashing at 0.5s on 0.5s off. **Float:** 1s on and 1s off
Charger	Charging can start when solar panel is >12V
Charger operation	Switch mode power converter at 31.24kHz maintains solar panel operation at maximum power output.

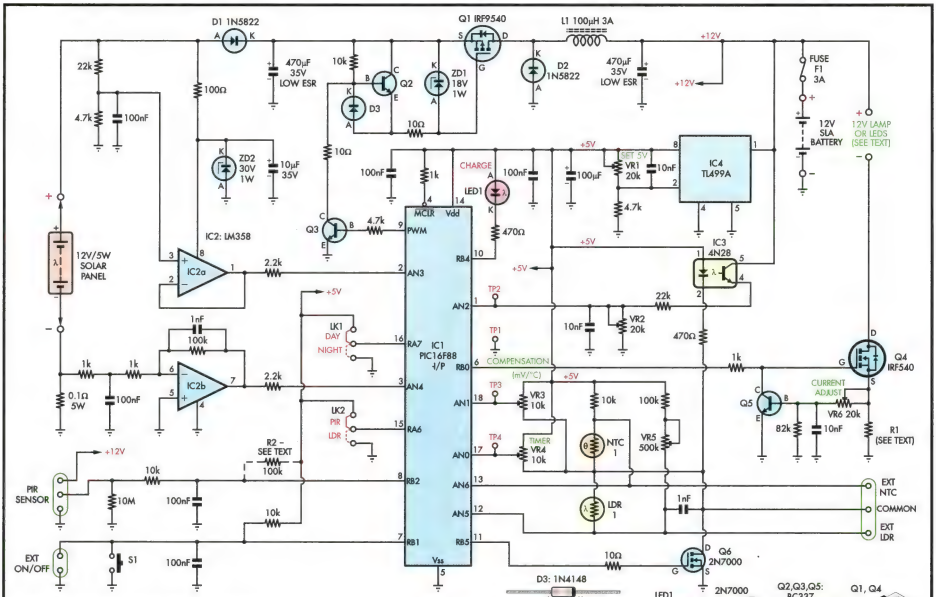


Fig.5: the circuit is based around a PIC16F88 microcontroller, IC1. It monitors IC2, the PIR sensor, switch S1, light dependent resistor LDR1 (for day/night sensing), the NTC thermistor and also controls lamp operation via Mosfet Q4.

Table 1: Lamp Operation

PIR (LK1)	LDR (LK2)	Lamp ON	Lamp OFF
In	Night	PIR movement detection or with S1 during night time only	Timer timeout, S1 or at dawn
In	Day	PIR movement detection or with S1 during day time only	Timer timeout, S1 or at dusk
In	Night (LDR1 disconnected)	PIR movement detection or with S1 during day and night	Timer timeout or S1
Out	Night	Day to night transition or with S1, night only	Timer timeout, S1 or automatically at dawn
Out	Day	Night to day transition or with S1, day only	Timer timeout, S1 or automatically at dusk
Out	Night (LDR1 disconnected)	S1 during day or night	Timer timeout or S1

5V to Q4's gate, allowing current to flow from its drain to source. If the current through R1 rises enough for the voltage across it to exceed 0.6V, transistor Q5 turns on and reduces Q4's gate voltage. This reduces the current flow. A steady state arises so that the voltage across R1 is kept at approximately 0.6V.

If R1 is 2.2Ω, about 270mA will flow through Q4 and the lamp. VR6, in combination with the 82kΩ resistor, acts as a voltage divider, allowing the current flow to be adjusted upwards. If VR6 is set for maximum resistance than the voltage across R1 will be 0.76V before Q5 turns on, allowing up to 345mA through the lamp.

2.2Ω for R1 is suitable for a lamp consisting of three 1W white LEDs in series. Their combined forward voltage is about 10.5V. With 0.76V across R1, this means that there will be 0.74V across Q4 (its minimum drop is around 0.1V in this case). With this setup, the lamp driver consumes some 0.51W (1.5V x 340mA) and the LEDs consume a total of 3.57W. Thus efficiency is about 87%.

If the 270-340mA range is inadequate then R1's value can be changed. For 3W star LEDs, use 0.68Ω, which results in a range of 0.9-1.1A. For standard 12V lamps, the current regulator serves as short circuit protection – a 0.33Ω resistor allow up to 2A before limiting occurs.

Charging

For charging, we use the switchmode step-down circuit previously described in Fig.3. Mosfet Q1 is a P-channel type that switches on with a gate voltage that is negative with respect to the source. The voltage at Q1's source (from the solar panel and diode D1) can range up to about 21V when the solar panel is not delivering current.

The gate is pulled negative with respect to the source via transistor Q3, a 10Ω resistor and diode D3. Transistor Q3 is pulse-width-modulated by the RB3 output of IC1 via a 4.7kΩ resistor.

When RB3 goes to 5V, Q3 is switched on and pulls the gate of Q1 low. The Mosfet is therefore switched on.

Transistor Q2 is held off due to its base being held lower than the emitter via the forward-biased diode D3.

The 10Ω resistor at the collector of Q3 limits initial zener diode current through ZD1 in the event that the gate voltage exceeds 18V. This zener protects the gate from breakdown with excess gate voltage. With extreme over voltage, transistor Q3 will come out of saturation, preventing little more than about 20mA current through the 18V zener diode.

When the output of RB3 is taken to 0V, transistor Q3 switches off and the base of Q2 is pulled to the Q1 source voltage via a 10kΩ resistor. Transistor Q2 switches on and pulls the gate of Q1 to the source and so switches off Q1. The switch-on and switch-off action for Q1 as controlled by the RB3 output of IC1 is at 31.24kHz.

Battery voltage is monitored at IC1's AN2 input via optocoupler IC3 and a resistive divider comprising a 22kΩ resistor and 20kΩ trimpot, VR2. This divider, or more properly the trimpot, is adjusted to so that the voltage appearing at AN2 is actually 0.3125 times the battery voltage.

The reason for this is so that the 5V limit of analog input AN2 is not exceeded – for example, a 15V battery voltage will be converted to just 4.69V. We'll cover this procedure in the setup later.

The resistive divider is not directly connected to the battery but via the transistor within optocoupler IC3, which connects the battery voltage to the divider whenever the LED within IC3 is on. The voltage between the collector and emitter of the transistor has a minimal effect on the battery voltage measurement, as it is only around 200µV.

The divided voltage is converted to a digital value by the IC's firmware.

The optocoupler LED is driven from the 5V supply through a 470Ω resistor and to 0V when Mosfet Q6 is switched on. The thermistor (NTC1) forms a voltage divider with a 10kΩ resistor across the supply when Q6 is switched on. The AN6 input to IC1 monitors this voltage and converts it to a value in degrees Celsius.

At the same time, IC1's AN1 input monitors the setting of trimpot VR3, which is also effectively connected across the 5V supply when Q6 is switched on. The AN6 and AN1 inputs are converted to a mV/°C value, which can range from 0mV/°C when VR3 is set to 0V to 50mV/°C when VR3 is set for 5V.

Power saving

As we just mentioned, Mosfet Q6 connects trimpots VR3 and VR4, the LDR and the NTC to 0V and also powers the optocoupler LED. Q6 is powered on with a 5V signal from the RB5 output of IC1. The Mosfet then momentarily connects these sensors to 0V so the IC1 microcontroller can measure the values. When Q6 is off, these trimpots, sensors and battery divider are disconnected from the supply to conserve the power drain from the battery.

One problem with using Q6 to make the 0V connection for the trimpots, battery and sensors is that these sampled voltages cannot be measured easily with a multimeter. This is because a multimeter will not be fast enough to capture the voltage as Q6 switches on momentarily. And we do need to measure some of these voltages for setting up.

For example, we need to be able to set VR2 so that the

Parts List – Solar Powered Lighting Controller

1 PC board coded 16105101, 133 x 86mm
1 UB1 box 157 x 95 x 53mm
4 3-way PC mount screw terminals 5.08mm pin spacing (CON1,CON2)
1 2-way PC mount screw terminals 5.08mm pin spacing (CON1)
1 100µH 3A Choke (Altronics L6522, Jaycar LF1272 or equivalent)
1 SPST PC mount tactile membrane switch with 3.5 or 4.3mm actuator (S1) (Altronics S1120, Jaycar SP0602)
1 10kΩ NTC thermistor (Altronics R4290, Jaycar RN3440 or equivalent)
1 LDR with 10kΩ light resistance, 1MΩ dark resistance (Altronics Z1621 or Jaycar RD3480 or equivalent)
4 IP68 cable glands for 6mm cable
2 4.8mm female spade crimp connectors
1 DIP18 IC socket
2 M205 PC mount fuse clips
1 3A M205 fast blow fuse
1 TO-220 U shaped heatsink 19 x 19 x 10mm
1 M3 x 10mm screw, nut and washer
2 PC stakes (TP1,TP2)
1 2-way pin header with 2.54mm pin spacing (TP3,TP4)
2 3-way pin headers with 2.54mm pin spacings (LK1, LK2)
2 jumper shunts for pin headers
1 100mm cable tie
1 100mm length of 0.7mm tinned copper wire or 4 0Ω links

Semiconductors

1 PIC16F88-I/P microcontroller programmed with 1610510A.hex (IC1)
1 LM358 dual op amp (IC2)
1 4N28 optocoupler (IC3)
1 TL499A regulator (IC4)
1 IRF9540 P-channel Mosfet (Q1)
3 BC337 NPN transistors (Q2,Q3,Q5)
1 2N7000 N-channel Mosfet (Q6)
1 IRF540 N-channel Mosfet (Q4)
2 1N5822 3A Schottky diodes (D1,D2)
1 1N4148 switching diode (D3)
1 18V 1W zener diode (ZD1)
1 30V 1W zener diode (ZD2)
1 3mm high intensity red LED (LED1)

Capacitors

2 470µF 35V (or 50V) low ESR
1 100µF 16V
1 10µF 35V
6 100nF MKT polyester
3 10nF MKT polyester
2 1nF MKT polyester

Resistors (0.25W 1%)

1 10MΩ 5%	2 100kΩ	1 82kΩ	2 22kΩ
4 10kΩ	3 4.7kΩ	2 2.2kΩ	4 1kΩ
2 470Ω	1 100Ω	3 10Ω	

Resistors (5W)

1 0.1Ω 1 0.33Ω – 3.3Ω (value selected from Table 1)

Mini horizontal trimpots (5.08mm pin spacings)

2 10kΩ (103) (VR3,VR4)
3 20kΩ (203) (VR1,VR2,VR6)
1 500kΩ (504) (VR5)

Miscellaneous

1 12V 3.3AH SLA battery
1 12V 5W solar panel array (Altronics N0005 or N0704, Jaycar ZM9091 or ZM9026 or equivalent)
Figure-8 wire, solder, 4-way alarm cable.

Additional Parts (as required)

1 Altronics low current PIR movement detector (IR-TEC IR-530LC) (Altronics SX5306)
or
1 PIR movement detector with NC relay contacts (preferably with 1mA or less standby current – will also need R2, an extra 100kΩ resistor)

LEDs

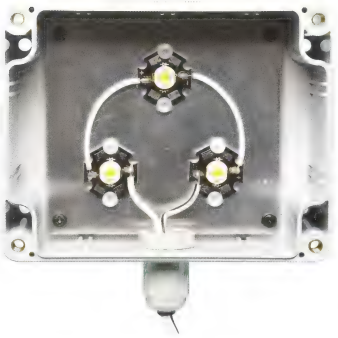
1W white LEDs (Jaycar ZD0424, ZD0426, ZD0508, ZD0510) (Altronics Z0251, Z0252A)
3W white LEDs (Jaycar ZD0532, ZD0534, ZD0442, ZD0-0444) (Altronics Z0258A, 0259A

LED drivers (see text: Controller has a LED driver built in)

Jaycar AA0592, Altronics M3310 for 1-6 LEDs at 1W
Jaycar AA0594 for 1-6 LEDs at 3W (Altronics M3320 for 1-3 LEDs at 3W)

12V lamps

IP67 3-LED modules (eg Jaycar ZD0490)
MR16 lamps (eg Jaycar ZD-0346-ZD0349)
10W Halogen (eg Altronics Z2400)
12V DC LED Globes (eg Altronics X2150)



Internal (above) and external shots of our 3-LED light which is perfect for this controller. You can just see the blurry LEDs through the translucent lid in the photo below. Construction details will follow next month.

battery divider is correct and to measure the timer and mV/°C values set with VR4 and VR3. In order make these measurements; Q6 is switched while ever S1 is pressed.

Other power saving methods includes how the charge LED (LED1) is driven. It is only used to show charging when there is supply available from the solar panel. Current to drive the LED is therefore provided from the solar panel instead of the battery. The only time this LED will light using battery power is if the thermistor is open or short circuit. In these cases, the LED flashes these indications at a low duty cycle, again conserving power.

Op amp IC2 is also powered from the solar panel itself. This arrangement is suitable because we only want to measure the solar panel voltage and its current whenever the solar panels are generating power.

Power for IC2 is derived from the solar panel via a 100Ω series resistor. A 30V zener diode limits transient voltages that could occur in long wiring that connects between the Solar Lighting Controller and the solar panel. Diode D1 prevents the battery from powering IC2 via Q1's internal diode and L1.

Solar panel voltage is monitored using a 22kΩ and 4.7kΩ voltage divider. A 100nF capacitor filters any transient voltages or noise that could be induced through long leads from the solar panel. Voltage is buffered by IC2a and the output is applied to the AN3 input of IC1. The voltage divider ratio allows for measurement of up to about 28V from the solar panel. Should IC2a's output go above 5V, the 2.2kΩ resistor limits current into IC1.

Current through the solar panel is measured by voltage developed across a 0.1Ω resistor. The voltage is only around 30mV with 300mA flowing. Voltage at the negative terminal of the panel does go (slightly) negative with respect to 0V when there is solar panel current flow.

This voltage is inverted and amplified by IC2b, which has a gain of -50. Therefore IC2b's output will be around 1V per 200mA of current flow from the solar panel. This output is applied to the AN4 input of IC1 via a current limiting 2.2kΩ resistor.

Note that the actual calibration of voltage and current is not overly important. Software within IC1 multiplies the voltage and current readings obtained at the AN3 and AN4 inputs to find where the maximum power point is for the solar panel. This calculation is not after any particular value but just the maximum in a series of power calculations. It does this calculation periodically once every 20 seconds and varies the on and off duty cycle of mosfet Q1 to find the duty cycle that provides the maximum power from the solar panels.

Power for the remainder of the Solar Lighting Controller circuit is from the 12V SLA battery via a TL499A regulator, IC4, a low quiescent current type that can run as a linear step-down regulator and as a switch mode step-up regulator.

We have used it as a 12V to 5V linear regulator, with the output voltage trimmed using VR1. Setting the output to 5V calibrates the analog-to-digital conversion within IC1, ensuring correct charging voltages for the battery.

Protection against reverse polarity connection of both the 12V battery and solar panel are included. If the solar panel is connected with reverse polarity, IC2 is protected because zener diode ZD2 will conduct in its forward direction, preventing more than 0.6V reverse voltage applied across its pin 4 and pin 8 supply rails. Diode D1 prevents reverse voltage being applied to the remainder of the circuit.

Should the battery be connected back to front, diode D2 will conduct via inductor L1 and the fuse, F1. The fuse will blow breaking the connection.

Construction next month

That's a fair amount to digest in one bite but broken down into functional parts, it's not that difficult!

Next month, we'll cover full constructional details and even show how we made some LED lights to go with the project. SC

CIRCUIT NOTEBOOK

Interesting circuit ideas which we have checked but not built and tested. Contributions from readers are welcome and will be paid for at standard rates.

Momentary switch teamed with latching relay

Merv Thomas is this month's winner of a Peak Atlas test instrument

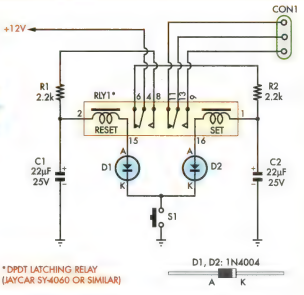
This circuit allows an SPST momentary pushbutton to act as a push-on push-off switch, using a DPDT latching (bi-stable) relay. It was originally intended to allow a single pushbutton switch on the dash of a vintage car to provide a latched function. The relay only draws current when it is being switched. At other times, the only current drain on the 12V supply is the leakage current of one 22µF capacitor, which is very low. It works as follows.

Assume that initially the latching relay is in the reset state, with pins 4 and 6 connected together. In this state, C2 charges up to +12V via 2.2kΩ resistor R2 while capacitor C1 remains discharged as it is not connected to the 12V supply.

If S1 is pressed, C2 discharges via the relay's "set" coil, diode D2 and S1. This switches the relay into its set position, connecting pins 4 and 8. C1 then begins to charge via R1.

While S1 is being held down, the relay does not return to the reset position because the current supplied via R1 is insufficient for the coil to latch the armature. As soon as S1 is released, current no longer flows though the coil so C1 can finish charging, ready for the next button press.

Once the relay has switched and C1 has finished charging, pressing S1 again causes the relay to switch back to the reset state via the same process.



The unused set of relay contacts can be used as an SPST or SPDT switch.

The circuit as shown has been tested with the Jaycar SY4060 relay. It will work with other DPDT twin-coil latching relays but the resistor and capacitor values may need to be adjusted to suit. Relays with lower resistance coils will need larger value capacitors and smaller value resistors.

Merv Thomas,
Mutarnee, Qld.

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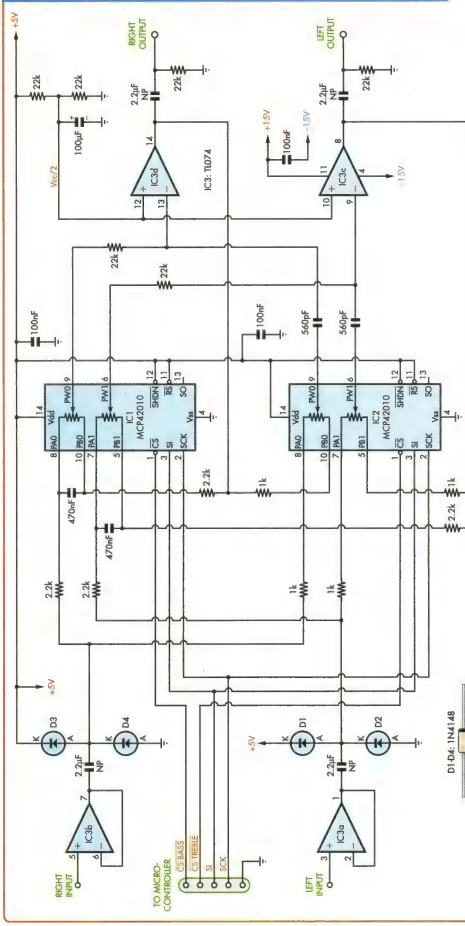


Digitally-controlled tone filter

This circuit is a Baxandall active tone control filter which can be driven by a microcontroller. The micro could also be fitted with an infrared receiver so that you have remote control of the treble and bass levels of a stereo audio signal.

Some of the component values, such as the 470nF MKT capacitors, have been changed from a typical Baxandall circuit to better suit digital potentiometers. Normally we would use 25kΩ - 100kΩ pots for the bass and treble adjustment but 10kΩ digital pots perform better than the higher resistance types.

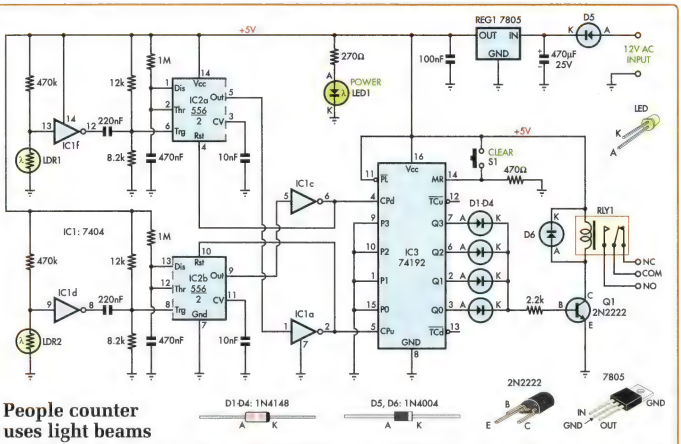
Digital pots typically run off much lower voltages than most op amps, in this case +5V. Hence, a dual supply is required, with balanced rails for the op amps and +5V for the digital potentiometer ICs. Virtually any audio op amps can be used as long as the supply rails are suitable.

Op amps IC3a & IC3b buffer the input signal which is assumed to be ground referenced. Their outputs are coupled via 2.2µF non-polarised capacitors to the Baxandall tone control network comprising the two MC42010 digital dual-gang potentiometers and the associated resistors and capacitors. Diodes D1-D4 protect the digital potentiometers from excessive signals input, clipping any signal above about 1.77V RMS (5V peak-to-peak).

Note that the entire Baxandall circuit is effectively based around op amps IC3c & IC3d. These two op amps are biased to +2.5V, as provided by a voltage divider consisting of two 22kΩ resistors and bypassed with a 100µF capacitor.

The bass and treble levels are controlled via the 4-line digital bus. Normally, both CS-bar lines are held at +5V. IC1's CS-bar line is pulled low to adjust the bass, while IC2's CS-bar line is pulled low to adjust the treble. The new cut/boost value is then sent via SPI, with MOSI driving the SI line. A value of 128 gives a flat response. Higher values (up to 255) provide boost and lower values (down to 0) cut.

The MCP42010 data sheet documents the SPI commands necessary



People counter uses light beams

This circuit keeps track of the number of people entering and leaving a room or building. The entrance is fitted with two photoelectric beams so that people passing through will break one beam before the other. The order differs depending on whether the person is entering or leaving and a counter is incremented or decremented in response.

If the counter value is non-zero, a relay is energised. This could, for example, turn lights on as the first person enters the room and turn them off when the last person leaves. A manual reset button is provided to correct any miscounts which could occur if two people pass when breaking the beams.

The circuit is based on a 7404 hex inverter (IC1) with only four sections used, a 556 dual timer (IC2) and a 74192 up/down decade counter (IC3). It works as follows.

LDR1 and LDR2 are positioned so that when a person enters the area, the beam to LDR1 is broken first. Since both sensors will be in close proximity, a single light emitter (mounted on the opposite side of the entrance) can be used to illuminate both.

When LDR1's beam is broken, its resistance increases, bringing inverter IC1f's input high and generating a negative pulse at the trigger pin of IC2a. IC2a is configured as a one-shot timer in order to provide a fixed pulse duration each time the beam is broken. When IC2a's output goes high, IC3's counter is incremented.

LDR2 and IC2b form an identical circuit which decrements the counter when LDR2's beam is broken. Since both circuits are triggered each time a person enters or leaves, whichever circuit is triggered first must inhibit the other for a short period. This is achieved by connecting the inverted output from each half of IC2 to the opposite reset pin.

As a result, if LDR1's beam is broken first, pin 10 of IC2b is temporarily brought low so that when LDR2's beam is broken shortly after, the counter will not be immediately decremented. The same happens in reverse if LDR2's beam is broken first.

Diodes D1-D4 provide a simple zero comparator at the output of IC3. If IC3's count is non-zero, at least one of the Q0-Q3 outputs from IC3 will be held high. In this case, transistor Q1 is turned on and the relay is energised. When the counter returns to zero, IC3's Q0-Q3 outputs will be low and so transistor Q1 will switch off.

Because IC3 is a decade counter, if more than nine people enter the area being monitored, the counter will overflow. If needed, additional 74192 decade counters can be daisy-chained in order to increase the maximum number to 99, 999, etc.

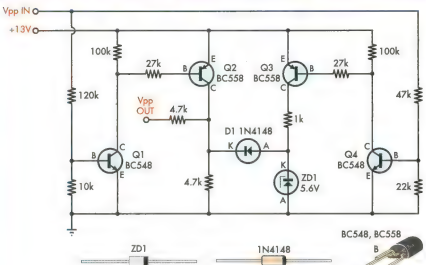
Note that it is possible to substitute the more common (and cheaper) 74HC04 and 74HC192 devices for IC1 and IC3. 74LS04 and 74LS192 are also acceptable substitutes.

Craig Kendrick Sellen,
Carbondale, PA, USA. ($50)

to set the pot "wiper" position. After the command has been sent, CS-bar should be brought high again.

The advantage of the MCP42010 (from www.futurlec.com) is that it comes in DIP packages and has two pots in a single IC, with low noise and crosstalk. It has 256 positions, which is plenty for this application.

Nicholas Vinen,
Silicon Chip.



Level translator for a PIC programmer

Some PICs require 12.75-13.25V on the V_{pp} line to be programmed correctly. This level translator circuit was designed to overcome a shortcoming of a cheap PIC programmer (bought via eBay) which would only drive the V_{pp} line to 11.9V, making reliable programming difficult.

If the V_{pp} IN line of the circuit is driven at normal logic voltages (eg, 3.3V or 5V), its output, V_{pp} OUT, will swing between 0V and 5V. However, if the input is brought above 8V then the output rises to 13V. This way, the IC's V_{pp} pin is not taken above 5V unless it is being programmed.

When V_{pp} IN is above 2V, transistor Q4's base rises above 0.6V, turning it on. Q4 turns on Q3, allowing current to flow through a 1kΩ resistor and 5.6V zener diode, ZD1. This forward-biases diode D1 so that its cathode (and thus the V_{pp} output) will be at 5V.

If V_{pp} IN exceeds 8V, transistor Q1 is turned on. Q1 pulls the base of Q2 low, turning it on and this pulls the output up to 12.9V. In this condition, D1 is reverse biased and the 5V level shifter has no effect on the output.

When V_{pp} IN is below 2V, all four transistors are off and the output is pulled to ground via a 4.7kΩ resistor.

The supply voltage should be between 12.9V and 13.2V to ensure that most PICs can be programmed properly. This can be achieved with an LM317-based adjustable linear regulator.

Andrew Partridge,
Toowoomba East, Qld. ($40)

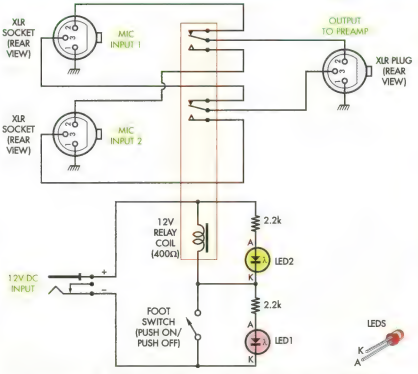
Switching balanced microphones using a foot switch

A foot switch can be used to select one of two balanced microphones by controlling a 12V DPDT relay. When the relay is off (ie, not energised), Mic1 is connected to the output XLR plug via the normally-closed (NC) contacts.

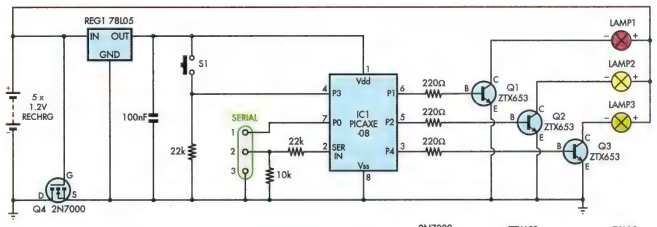
When the relay is on, Mic2 is connected via the normally-open (NO) contacts. A 12V DC plugpack drives LED1 via the 400Ω coil of the relay and the 2.2kΩ resistor. When the relay is on, LED1 is off and LED2 is on.

The Jaycar SY4061 DPDT relay or similar can be used. The 12V DC plugpack should be rated at greater than 40mA. Note that the 12V supply negative connection must not connect to the pin 1 earth for the XLR sockets and plug. This is to prevent noise from being injected into the microphone lines when switching.

John Clarke,
Silicon Chip.



Use this simple circuit to select between two balanced microphones using a foot switch. When the foot switch is open, Mic Input 1 is selected. Conversely, when the switch is pushed closed, Mic Input 2 is selected.



NOTE: LAMPS INCLUDE MULTIPLE LEDS AND CURRENT LIMITING

PICAXE traffic light controller

This traffic light controller was built as part of a fancy dress costume. Three different people wore a traffic light array (ie, red, amber and green lamps) based on torches which used a cluster of white LEDs with suitable current-limiting resistors and drawing 400mA at 6V.

Cellophane paper was used to obtain the red, amber and green tint.

A PICAXE chip controls the light sequencing. Power comes from five 1.2V rechargeable cells, resulting in a supply voltage of 4.2-7.5V. The 78L05 regulator ensures that the PICAXE's 5.5V maximum supply limit is not exceeded.

As the battery discharges, the IC's supply will drop below 5V due to the 78L05's dropout voltage but since it can operate down to 2.7V this is not an issue.

The 2N7000 Mosfet provides reverse supply protection without the voltage drop of a diode. ZTX653 transistors were chosen for Q1-Q3 because they have a low Vce saturation voltage (0.25V at 600mA), maximising the voltage available for driving the LEDs.

Depending on how long S1 is held down, four different functions are available:

(1) **< 2 seconds:** manually cycles through colours;

(2) **2-4 seconds:** automatically cycle – 10 seconds green, 2 seconds yellow, 10 seconds red;

(3) **4-6 seconds:** randomise light colour and timing;

(4) **> 6 seconds:** standby – all lights out, current draw is 2mA.

Photo credit: Bernard Golder

The software (TrafficLights.bas) can be downloaded from the SILICON CHIP website.

Paul Vaughan,
Christchurch, NZ. ($45)

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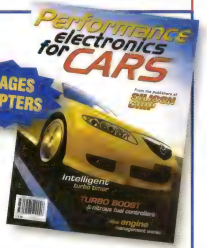

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SERVICEMAN'S LOG

The perils of salvaged computer parts

A little knowledge can be a dangerous thing so why do people delve into the insides of computers when they know almost nothing about them? It can certainly make life difficult for anyone who has to sort out the inevitable problems.

My first two stories this month are from A. F. of NSW. The first concerns a computer user who definitely didn't know what he was doing. Here it is in his own words . . .

Leon's computer

Leon hammered on my front door early one Sunday morning. According to him, his monitor had just blown up and he wanted to borrow mine so that he could complete some urgent work. I had not yet finished my coffee and it was Sunday but I don't charge my neighbours for my services, in case I need help from them one day.

I said I would be over in 30 minutes with my spare flat screen and would also take a look at his monitor for him. When I got there, I found that Leon's CRT monitor presented a blank screen, although the green power LED was on. "See, it's dead!", Leon told me.

I did not want to expose his ignorance too rudely, so I told him that another test would have to be made to prove it one way or the other. This involved unplugging the monitor cable from the PC's video card. I did this and the "No Video Signal" warning immediately appeared in colours on the screen, so the monitor was in fact OK.

Leon stared in disbelief and said "But where is the XP start-up screen?" He really wasn't following what was going on.

When I restarted the computer, I noticed an unusual silence from it – there were no beep codes and no noises from the hard disk drives. By now, Leon was also silent and it was time to find out why the computer was lifeless.

First, I removed the cover and closely examined the mainboard, looking for any loose power cables or signs of mechanical damage. It was then that I noticed that the CMOS battery had been installed upside down, as I could see the circle of the insulating material on the end of the battery. So how had that happened? It was a strange "fault" to say the least.

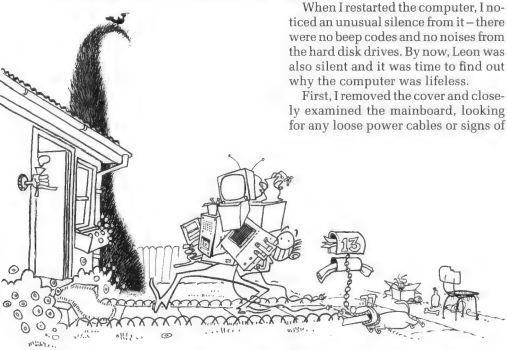
I removed the coin cell and it measured 2.98V under a 1mA load, which was acceptable. I then re-installed it, the right way up this time. It didn't fix the main problem of course but it was still a fault that had to be corrected.

Next, I pulled the IDE cables off the disk drives, explaining to Leon as I did so that the best way to find the fault was to simplify things by eliminating the plug-in hardware. There was still silence from the mainboard, so I removed the two sticks of dissimilar RAM. This time, when the machine was rebooted, there was a beep from the mainboard, indicating that it was now working.

By inserting the RAM sticks one at a time, I soon found which one was locking up the system and preventing boot-up. The rest was easy. I reinstalled the good RAM stick, connected the IDE cables and the monitor and switched on. The computer immediately sprang to life, the desktop loaded and after several successful restarts, I pronounced that it was cured.

So how had this computer worked with a reversed CMOS battery before it finally halted with a faulty stick of RAM? As I replaced the computer cover, I explained to Leon the details of this double-fault situation and said he must be the unluckiest person around, to have had such a weird double failure.

So what was going on? It was only then that finally Leon "fessed" up. He explained that he had swapped his mainboard from his old case to a better one he had found on the kerbside during a council clean-up. During this process, he had decided to install a new CMOS battery but hadn't realised that it could be installed upside down. He had also decided to fit the



stick of RAM that was in the kerbside computer into his own computer. It fitted, so why not?

And so the mysteries ended. So much for his original story of his monitor blowing-up! If he had told me the full story in the first place, he would have saved me a lot of time and effort!

I tried hard not to show my annoyance at being made a sucker, while thinking that if I were charging him, a threefold increase in the price would have made me feel much better.

My neighbour Wally

Wally is undoubtedly the best neighbour I have. He is the kindest, hardest-working person I have ever known, a truly "Bonzer Bloke". When the steel frame on my gate snapped during a windstorm, Wally came around with his arc welder on wheels, without me even asking for his help.

Now it had been some years since I had used a single phase welder at my house and when Wally had trouble striking the arc, it took me several minutes to realise that he had blown the 15A fuse. I crossed my fingers, gave a silent prayer to the Patron Saint of Housefires that my house would not be consumed in a fireball, and used a double strand of 15A fuse wire. I swear I heard the arc welder give a sadistic hum of pleasure before there was a bang and molten copper balls and smoke erupted from the fuse box. Silence echoed through the house.

Wally's solution was to use a six-inch nail instead of a fuse but I knew I had already used up my prayer quota. I then remembered that before the new gas stove had been installed in our kitchen, we had an electric stove and this used a 30A fuse. When the stove had been removed, the 30A fuse had been changed to 15A and the wiring had been terminated in an ordinary 15A wall socket.

I refitted the 30A fuse and Wally's welder sprang into life. Wally always looked at peace when he had a cloud of smoke floating around his head from the welder electrode. And with 30A of juice at his disposal, my gate was soon repaired.

But of course, what goes round comes round and when Wally asked for my help with the wiring in his old Transit Van, I readily agreed. What I didn't realise was that he had changed his gearbox from a manual to an automatic and that he wanted me to change the vehicle wiring, according to a crude wiring diagram drawn on a scrap of cardboard by some bloke behind the counter at the wrecking yard.

As an aside, Wally had also fitted a new engine from the reconditioners but had forgotten to fill it with engine oil and seized it. I guess his workmates had nicknamed him "Wally" as a warning to others that although he was a good worker, Wally's lift did not always ascend to the top floor!

My immediate problem was to translate the greasy pencil drawing on a piece of cardboard into a working and safe gearbox wiring conversion. The worse part was the vehicle dropping sand into my eyes while I was looking up to find the wiring harness. The grease on my hands later washed off easily but it took days before my eyes ejected all the gritty particles.

Items Covered This Month

- Leon's computer
- My neighbour Wally
- Grundig Elegance MFW70-3210/8 (CUC 1934 chassis)
- A 5-minute job – not
- The forgetful modem

I suggested at one stage that maybe he should wash the vehicle before we did any further work on it but that just produced a glazed look in Wally's eyes.

The cardboard wiring diagram simply showed that the hot lead to the ignition switch was wired through the switch on the gearbox. If the gearbox was in any of the Drive positions or in Reverse, then there was no power to the ignition coil or starter solenoid. Conversely, in Neutral or Park, power was applied via the switch.

Wally had not driven an automatic before, so when the conversion was complete, I had to show him how the vehicle would only start in Neutral or Park and not in any of the Drive positions. I also explained that he would have to have my work and his conversion checked by a registered motor mechanic, before he could have the modifications registered with his in-

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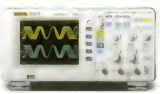

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surance company. But even as I spoke I again saw that glazed look appear in Wally's eyes.

It was two weeks later that I heard about Wally's vehicle rear-ender. His son had reversed the van into his own car! It took two months to learn the full story, as Wally always seemed to be out when I called. Apparently, soon after I finished wiring the gearbox, Wally had driven up to the local store for some cigarettes. When he got there, he switched the engine off with the gearbox in Reverse and left it there.

When he returned to the vehicle it would not start, as it was still in Reverse. He phoned his son for help, who brought a handful of clip leads. Using these, his son bypassed the gearbox interlock, routing power straight from the battery to the coil and to the starter solenoid.

The vehicle started and as it did, Wally's son blipped the throttle. And because it was in Reverse, the vehicle took off backwards and hit the vehicle behind. Wally's son was also in no danger of being a tall poppy.

Of course, Wally was very matter of fact about it all and was completely unconcerned as evidenced by that glazed look in his eyes.

Grundig TV set

My next story is from my own service bench. I was called out to a Grundig CRT TV that was dead. Once again, the owner ignored my advice that it wasn't worth fixing and nor could he be persuaded to bring the set in himself. That meant that he was up for a call-out fee on an old CRT set and that was before I even started to fix it.

The reason he didn't want to bring it in quickly became obvious – his house was on top of a fairly steep hill overlooking the ocean. Ever a sucker for punishment, I manfully climbed about 1000 steps to reach the entrance, by which time I probably felt worse than his telly.

The set was a Grundig Elegance MFW70-3210/8 (CUC 1934 chassis) and I was convinced, sight unseen, that the cause of the problem was corrosion from the sea air. This had probably affected either the flyback transformer or the capacitors in the voltage doubler circuit (or perhaps both).

I also felt sure that when he discovered the cost of these parts, the owner wouldn't feel any better than I did!

Anyway, I thought I had better check my theory before giving him the bad news. When the set was switched on, the front-panel LED went from red to yellow but didn't quite go to green. The set was otherwise quite dead with no +A voltage and yet it showed no signs of stress or component failure.

I removed the chassis from the cabinet and examined it closely but could not find any clues. There was nothing for it – it had to go to the workshop, minus the heavy CRT and cabinet. I would have to suss it out there with dummy loads, etc.

Anyway, I informed the owner of this and also told him that it could well be the flyback transformer and that it could be expensive. I would prepare a more accurate estimate for him when I knew more and with that I renegotiated the 1000 steps down the mountain precipice, carrying the chassis and my tools.

Back at the workshop, I ran a few checks which, strictly speaking, I really could have done at the house had I been in the mood. However, I was more comfortable dealing with this problem in my workshop. At least I could make a mess on my own bench and I wasn't dead with exhaustion after having climbed all those steps to Mr Coulton's castle in the sky. Machu Picchu would be a snack after that.

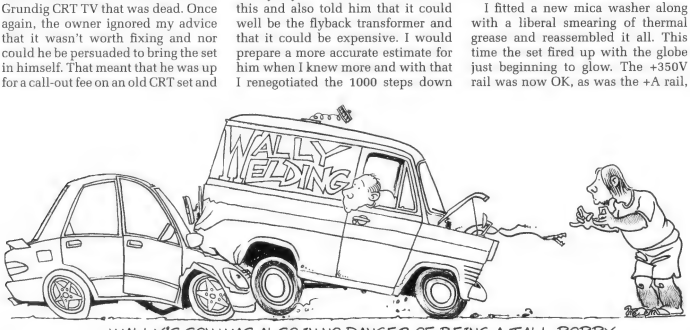
I soon discovered that the 2A anti-surge fuse (Si60501) measured open circuit. I could not measure any shorts in this 350V circuit and the fuse looked perfect, with no signs of blackening. So was the problem caused by a power surge? I replaced the fuse with a shiny new one and connected the TV to the mains with a 200W light globe in series.

I switched it on and the globe lit brightly – there was a hidden short circuit after all!

I was convinced that it was either FET T60506 or a capacitor that was faulty, so I removed all the likely suspects and checked them. They were all OK except for a vital clue I found on the FET heatsink. There was a small but distinct round mark on it where the metal had partly melted.

Next, I examined the insulating washer and discovered a very small hole/puncture in line with a corresponding mark on the FET. So it looked like the FET had been arcing across to the heatsink.

I fitted a new mica washer along with a liberal smearing of thermal grease and reassembled it all. This time the set fired up with the globe just beginning to glow. The +350V rail was now OK, as was the +A rail,



~ WALLY'S SON WAS ALSO IN NO DANGER OF BEING A TALL POPPY

so I removed the 200W globe and fitted it where the horizontal deflection yoke would normally go.

This time, the chassis fired up without any distress and all voltage measurements were correct. I resubmitted a cheaper estimate for Mr Coulton which he gratefully accepted.

I returned to the mountain and reassembled the chassis back into its case. To my relief, the set fired up with a good picture and sound, so I collected the moolah and hiked back to the car. I think my earnings will be blown on a good physio though!

My next story comes from M. S. of Keilor in Victoria and strikes a familiar chord.

A 5-minute job – not

We've all had customers who claim that a job should take "no more than five minutes". It invariably turns out to be wishful thinking on the customer's part but then we all want to minimise labour costs.

I recently got a phone call from a bus company requesting my services. I'd never done any work for them before and after this job, I'm not in any hurry to hear from them again. This guy started straight out with the "it's only a 5-minute job" routine. "All I want you to do is wire up the rear mount TV. We've wired it every way possible and it doesn't work".

When I got there, sure enough, the TV didn't work. It was dead and the reason was quite simple – there was no power to it. I eventually managed to trace one of the main earths (negative power) all the way to the front of the coach but this involved removing most of the inside overhead panels and the ventilation system. That was at the 16-hour point of his 5-minute job. The look on the owner's face was priceless when he saw the inside of his coach but there was no other way if I was going to fix the problem.

I eventually found the problem at the 23-hour point. It was at the front of the coach and it turned out to be a rusty earth bolt. And as I discovered, this was also preventing other electrical items from working properly although the owner didn't think to tell me that up front.

Once the problem had been fixed, the TV not only worked properly but so did all the other electrical items in the coach, including the fuel gauge!

After about 36 hours, I finally had everything back together and I had an almost happy customer. An invoice was negotiated and he promptly paid up, although it was rather more than he originally bargained for. So much for his 5-minute job – unless you think of it as 432 separate 5-minute jobs strung together!

My final story for the month comes from D. S. of Maryborough in Qld and concerns a modem that kept losing its settings. Here it is . . .

The forgetful modem

This story began when a friend contacted me and asked if I could help with her internet connection. The issue was that the modem would lose the login information and she would then have to reload this information into the modem each time she wanted to access the internet. Thinking it would be a 5-minute fix, I said that I would pop around that afternoon and sort it out. How wrong I was.

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Serviceman's Log – *continued*

The modem in question was a D-Link DSL-302G. Now this has been a very successful modem and a large number are still operating without problems. It's a small unit and does not have all the bells and whistles that some modems have but it works very well. This particular model was supplied by several ISPs to new ADSL users and as such, the modem was loaded with that ISP's own version of the firmware. In this case, the modem was supplied by Optus and had the Optus firmware installed.

First, I checked the PC's network and internet settings and checked that the IP and DNS addresses were correct. Then I opened a CMD window and using the *ipconfig /all* command, checked the LAN and gateway settings. The returned data told me that all was well and confirmed that the modem's DHCP software was operating and assigning IP addresses as it should.

A quick "ping" command also gave me the connection speeds and indicated that no data packets were getting lost. So all was looking good so far. I then checked all the cables and power connections and again, everything was just as it should be.

Now, if the modem was losing its internal settings, maybe that was a power supply issue, so I replaced the original plugpack with a spare I had, rechecked all the cables and rebooted the modem. Everything worked fine and after explaining my findings to my friend, I went home thinking that the problem had been solved.

Unfortunately, it wasn't going to be that easy because she was back on the phone the very next day. "It's done it again" she told me with a rather miffed tone in her voice. "Don't touch it" I said and went straight around to her house with a spare modem.

When I arrived, I got into the modem's configuration page (by entering 10.1.1.1 into the browser) and after entering the username and password, I began to scroll through the various options. Sure enough, the ISP logon details had returned to the factory defaults!

After setting up my spare modem for her, I returned home with the offending modem in my grasp. It was time for some troubleshooting. First, I checked with Optus to find out if any firmware upgrades were available but no luck there. I then powered the modem up, entered my own ISP log-on information and left it hooked up.

It worked flawlessly for several days until one morning, when I turned it on, I couldn't connect to the "net". On checking the Configuration page, I found that it had lost all the log-on settings again.

Now that I knew it wasn't a PC or network issue, I contacted D-Link and asked their advice. The gentleman I spoke to was extremely helpful. He agreed that it was possibly a firmware issue and emailed me an update for the firmware. This proved to be easy to install – the software simply found the modem and installed itself.

This upgrade opened up a few extra features in the modem but apart from that, was identical to the Optus firmware. I then re-entered the settings again and used the modem for the rest of the day without a hitch. However, when I tried to use it the next morning, it had reset itself again.

It was time to take a look under the bonnet!

After opening the case, I could see immediately what the likely cause of the problem was. This modem runs off a 9VAC plugpack and its internal power supply circuitry consists of quite a few inductors, a few surface-mount transistors, several electrolytic capacitors and two surface-mount power control IC's. The problem was that several of the electros had "bulging top" disease. All had leaked and two had even decided to "launch" their cans, the latter only coming half way off as the lid of the case prevented them from going all the way.

I made a list of the electros I would need – a couple at 100µF 50V, three at 220µF 35V and a handful of 47µF and 100µF 25V units. All were 105°C types and that indicated why they had failed. My friend had placed the modem on her desk but in a position where the airflow through it was severely restricted. As a result, the electros had overheated and eventually failed.

The circuit is protected by a fuse which was still intact and the modem still worked each time after the ISP's info had been re-entered. It's a wonder that it continued to work at all. The case does have cooling vents and the unit is supplied with rubber feet but the feet had never been used and the airflow around the modem was dismal.

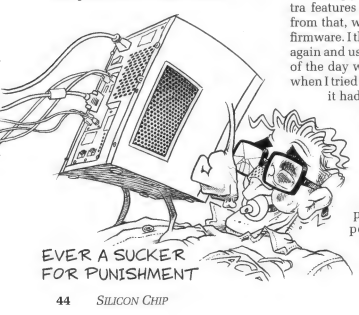
Replacing the faulty parts was a pain because the board is double-sided and a ground plane covers nearly the entire surface on the non-component side. The resulting copper forms an extremely good heatsink and so a great deal of heat is necessary to remove any parts.

As a result, some pads and tracks were damaged and these had to be repaired before the new parts were fitted. A couple of the larger electros also had to be fitted off the board but I eventually got the job done.

The repaired modem has now been running quite happily for several weeks. It's been fitted with the supplied feet and has been relocated on my friend's desk so that it now receives an unrestricted airflow for cooling. I was surprised at just how hot these and other modems get during operation and I now advise other friends to place their modems in open space.

Undoubtedly, there are many people who would say "why bother, why not just purchase a new modem?" Well, to me, this "throwaway" society of ours is irritating.

Once, you would repair anything. Nowadays, it gets thrown out. It's no wonder that landfills are overflowing and our planet is being slowly poisoned by the chemicals that leech out of the things we throw away. SC



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More Camera Clearance lines on page 5

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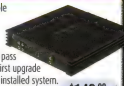

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Refer: Silicon Chip Magazine May 2010

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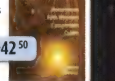

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Save On Your Electricity Bill!

Deluxe Mains Power Meter

In addition to telling you the cost of electricity consumption of an appliance plugged into it and the amount of power used in kilowatt hours, it will tell you how many cumulative kg of CO_2 the appliance is putting into the atmosphere. Battery included.

$29.95

- Dimensions: 120(L) x 58(W) x 40(H)mm

MS-6118

Wireless 3 Outlet Mains Controller

Plug in up to 3 mains appliances rated up to 10A and use the remote to turn each one on or off individually or all together. One of the outlets also has an LED night light that's also operated with the remote. Not just for couch potatoes, this also has obvious benefits for the elderly or disabled.

- 433MHz
- Remote battery included
- Remote measures: 125(W) x 45(H) x 17(D)mm

MS-6142

$44.95

Surge/Overload Protected Powerboards

Individually switched powerboards provide a high level of protection from overload and surge, with extra-wide spacing to take bulky mains plugpacks. Ideal for home theatre, computers, TV and video or audio systems.

- Extra-wide spacing to take mains plugpacks
- Individually switched
- Surge and overload protected
- 4 or 6 way

FROM $19.95

4 Way Powerboard
Cat MS-4064 $19.95

6 Way Powerboard
Cat MS-4066 $24.95

Marine Keyswitch

SPST heavy duty key switch with 2 keys. 21mm mounting hole in panels up to 25mm thick. Screw terminals.

SM-1042

$24.95

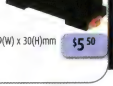
SPST Heavy Duty Pushbutton Marine Switch

SPST momentary action, brass body with large chrome-plated actuator. Can accommodate panel thickness of up to 22mm. Mounting hole 16mm, screw terminals.

SP-0701

$19.95

DIN Rail Mount Relay Socket



DIN rail mounting base for SY-4009. Also has 4mm holes so can be screw mounted to a chassis.

- Size: 71(L) x 29(W) x 30(H)mm

SY-4004

$5.50

Merit Plug to Cigarette Lighter Socket

Allows you to connect mobile phone chargers and other cigarette lighter plugged devices into vehicles equipped with a Merit socket.

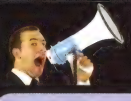
PP-2099

$12.95

All Savings are based on Original RRP

Better, More Technical

To order call 1800 022 888



MEGA MAY

Don't forget Mother's Day • May 9th

Great Gift Ideas For Mum

Rhinestone USB Keyboard

She has style, she has flair, now Mum can have the keyboard to match. Features 21 hot keys including 3 ACPI keys for easy access to the internet, email and multimedia applications.

- Compatible with Windows 95/98/ME/NT/XP
- Dimensions: 460(L) x 180(D)mm

GH-1899 Was $59.95

$49.95
SAVE $10.00

4 Port Coloured Flexible USB Hub

Four port USB hub with a different bright colour for each port. Funky and compact, keep one handy in the notebook bag just in case.

XC-4878 Was $15.95

$10.95
SAVE $5.00

LED Night Light with Sensor

$9.95

LED Night Light with Sensor

No need to stub your toe when you get up in the middle of the night. Keep one of these plugged in and it will give you enough light to see where you're going. Operates automatically.

- Rotates through 360° to light any direction
- Automatically comes on in darkness
- Unobtrusive size - smaller than a double adaptor

ST-3181

Wireless LED Wall Light

This stylish wall light with super bright LEDs is an extremely versatile lighting solution that comes complete with remote control and mounting brackets. No need for an electrician - installation is childsplay for the home handyman. Includes DC socket for plugpack connection.

- 7 Super bright LEDs
- One touch ON/OFF/DIMMER
- Dimensions: 170(H) x 75(W) x 90(D)mm
- Stand alone requires 2 x AAA and 3 x AA batteries

ST-3178 Was $29.95

$14.95
SAVE $15.00

MR16 3 x 2W CREE® Downlights

Designed for long life, and using the latest in high intensity technology, these MR16 downlights pump out brilliant lumens of white light.

MR16 3 x 2W Cool White Cat. ZD-0353 $74.95

- Lumens: 450
- Colour temperature: White 5000 - 7000k
- Lens: 38 degree
- Dimensions: 50(D) x 63(L)mm

MR16 3 x 2W Warm White Cat. ZD-0354 $74.95

Lumens: 310
Colour temperature: 2700 - 3500k
Lens: 38 degree
Dimensions: 50(Dia) x 63(L)mm

$74.95 each

3 Piece LED Puck Light Kit

3 x 1W puck lights that can be surface mounted or recessed to fit into your décor. They're powered by a single plugpack with a distribution block on a 2 metre cable, and each light has its own 600mm cable, so you can easily install them yourself.

- Fashionable cool white colour
- More than 30,000 hours life
- Power supply 12VDC 1A
- Light size: 72(Dia) x 28(H)mm

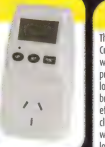
ST-3894

$149.00

Mains Power Meter

The meter can tell you how much an appliance is costing to run and tracks the actual power being used. It can also display the instantaneous voltage or current being drawn as well as peak levels etc. 10A max rating.

MS-6115 Was $29.95



$19.95
SAVE $10.00

'000s Sold Every Month

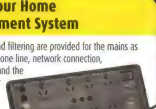
Cree® LED Torch Clearance

These fantastic X-Glow torches utilise Cree® high performance LEDs, which are renown for providing superior light and longer globe life than other brands. Incredibly energy efficient, Cree® LEDs produce a clear smooth beam of brilliant white light with minimal energy lost through residual heat. These X-Glow torches feature robust water resistant aluminium casings for heavy duty use, and they will even cold start in sub-zero temperatures.

80 Lumens ST-3372 Was $47.95 Now $29.95 Save $18.00
136 Lumens ST-3374 Was $64.95 Now $34.95 Save $30.00
176 Lumens ST-3376 Was $69.95 Now $39.95 Save $30.00
LIMITED STOCK

Protect your Home Entertainment System

Surge protection and filtering are provided for the mains as well as your telephone line, network connection, satellite/cable TV, and the TV antenna. Further protection is provided by the built-in 10A circuit breaker.



See website for detailed specs.
MS-4024 Was $64.95

$49.95
SAVE $15.00

Switchmode Plugpacks with USB Outlets

Slimline, lightweight, and featuring manually selectable variable voltage outputs. All are MEPS compliant and each come supplied with 7 plugs and a USB output socket.

7.2 Watt 3 - 12VDC 600mA
Dimensions: 69(L) x 39(W) x 31(H)mm
Cat. MP-3310 $19.95

18 Watt 3 - 12VDC 1000mA
Dimensions: 75(L) x 60(W) x 40(H)mm
Cat. MP-3312 $24.95

18 Watt 3 - 12VDC 1500mA
Dimensions: 80(L) x 60(W) x 50(H)mm
Cat. MP-3314 $29.95

27 Watt 3 - 12VDC 2250mA
Dimensions: 80(L) x 65(W) x 50(H)mm
Cat. MP-3316 $34.95

FROM $19.95

Mains Powered Universal Battery Charger

An economical unit that can charge Ni-MH batteries as well as Ni-Cd batteries (Yes, even 9V Ni-MH). It has a discharge function for proper Ni-Cd battery cycling and a battery tester for 1.2 & 1.5 volt batteries.

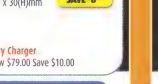
- Recharges AAA, AA, C, D, and 9V batteries
- Recharges batteries singularly or in groups
- Includes battery tester for 1.2V to 1.5V cells
- Accepts various combinations of batteries
- 200(W) x 50(H) x 95(D)mm
- Note: will not discharge standard 9V batteries

MB-3505 Was $24.95

$19.95
SAVE $5.00

In-Car Ni-Cd & Ni-MH Battery Charger

Recharges 2 x AA or 2 x AAA Ni-CD or Ni-MH batteries using Delta V voltage detection which ensures the batteries are charged to their optimal levels for long life. Keep a spare set of batteries topped up and ready to go, wherever you are.



- Includes bad cell detection
- Delta V detection
- 900mA charging current for AA batteries
- 450mA charging current for AAA batteries
- Dimensions: 130(L) x 45(W) x 30(H)mm

MB-3552 Was $18.95

$10.00
SAVE $8.95

Also available:
Advanced ANSMANN Battery Charger
Cat. MB-3554 Was $89.00 Now $79.00 Save $10.00

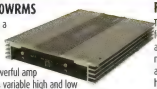
www.jaycar.com.au

All Savings are based on Original RRP

Jaycar Electronics

Mega Car Amp Clearance Sale

Precision Response Car Amplifier 2 x 150WRMS



This amp can be used as a standard stereo amp or bridged to provide a massive 500WRMS x 1 into a 4 ohm load. A powerful amp at a great price. Features variable high and low pass filters, bass boost and pass through RCA.

- 2 x 150WRMS @ 4 ohms
- 2 x 255WRMS @ 2 ohms
- 1 x 500WRMS @ 4 ohms bridged
- Dimensions: 340(L) x 258(W) x 50(D)mm

AA-0424 Was $219.00 Limited Stock

$179.00
SAVE $40.00

Precision Response 5 Channel Full Range Car Amp

This award winning amplifier features four full range channels plus a subwoofer channel. The main channels have adjustable gain and variable high-pass filters; the fifth channel has adjustable phase, variable low-pass filter, and adjustable gain.

- 4 x 60WRMS + 1 x 225WRMS @ 4 ohm
- 4 x 90WRMS + 1 x 340WRMS @ 2ohm
- 2 x 180WRMS + 1 x 340WRMS @ 4 ohm bridged

AA-0458 Was $449.00

$399.00
SAVE $50.00

Response Car Amp 4 x 100WRMS

An ultra-powerful 4-channel amplifier with output exceeding 100WRMS per channel or 300WRMS in bridged mode at 4 ohms. Features variable high and low pass filters, and pass through RCA.

- 4 x 130WRMS @ 4 ohms
- 4 x 190WRMS @ 2 ohms
- 2 x 380WRMS @ 4 ohms bridged
- Dimensions: 400(L) x 258(W) x 50(D)mm

AA-0426 Was $349.00

$299.00
SAVE $50.00

Precision Response 4 x 100WRMS Full Range Car Amp

A very efficient amp designed to drive full range speakers and is able to produce 550W bridged. It has insert-type connectors, variable high and low pass filters and variable bass boost.

- 4 x 130WRMS @ 4 ohm
- 4 x 190WRMS @ 2 ohm
- 2 x 380WRMS @ 4 ohm
- Dimensions: 300(L) x 170(W) x 50(D)mm

AA-0456 Was $399.00 Limited Stock

$319.00
SAVE $80.00

Response 1000WRMS Linkable Monoblock Car Amp

Monstrous, eardrum-puncturing power. You also get variable bass boost, adjustable phase shift, low pass filter and master/slave operation. Optional remote bass gain controller.

- 1000WRMS @ 1 ohm mono
- 600WRMS @ 2 ohms mono
- 1800WRMS @ 2 ohm linkable, dual mono

AA-0460 Was $399.00

$349.00
SAVE $50.00

Vifa 5" Component Car Speakers

Vifa's patented Hearing Optimised Driving (HOD) technology accounts for harsh in-car audio environments and drastically improves the sound production quality of your car audio system. Featuring super strong strontium magnets, Vifa's patented complex cone design, 36mm silk dome tweeter and a Butterworth crossover circuit; these component split systems reproduce unparalleled crystal clear sound that sounds more home theatre than car audio.

Vifa 5" Component Split Speakers
- 60WRMS @ 4 ohms
- 50Hz-20kHz

Cat. CS-2398 Was $219.00

$179.00
SAVE $40.00

Vifa 6.5" Component Split Speakers
- 80WRMS @ 4 ohms
- 45Hz-20kHz

Cat. CS-2399 Was $249.00

$199.00
SAVE $50.00

Vifa Car Speaker Grilles

Car speaker grilles to suit our range of Vifa car speakers, but will suit many other car audio applications. Made from perforated steel, finished in black.

5" Car Speaker Grille	Pair Cat. AX-3600	$9.95
6" Car Speaker Grille	Pair Cat. AX-3602	$12.95
6 x 9" Car Speaker Grille	Pair Cat. AX-3604	$14.95

Vifa Coaxial Car Speakers

If you value sound quality, true high fidelity mid range drivers like these are a must for your car audio. All Vifa coaxials feature the legendary Vifa silk dome tweeters, strontium magnets and composite diaphragms. Available in 2 or 4-way configuration.

Vifa 5" 2 Way Speakers
- 60WRMS @ 4 ohms
- 50Hz-20kHz
- 87.9 dB SPL @ 1W, 1m

Cat. CS-2393 Was $119.00

$99.00
SAVE $20.00

Vifa 6.5" 2 Way Speakers
- 80WRMS @ 4 ohms
- 45Hz-20kHz
- 86.3dB SPL @ 1W, 1m

Cat. CS-2395 Was $169.00

$129.00
SAVE $40.00

Vifa 6 x 9" 4 Way Speakers
- 150WRMS @ 4 ohms
- 35Hz-20kHz
- 90 dB SPL @ 1W, 1m

Cat. CS-2397 Was $229.00

$189.00
SAVE $40.00

Vifa Premium Subwoofers

These premium range Vifa car subwoofers produce genuine high fidelity sound quality. With dual voice coils, high power handling and die-cast aluminium chassis, they don't just deliver brilliant low-register bass clarity but also thump tremendous SPLs like only Vifa speakers can. 10" or 12" models available.

Vifa 10" Subwoofer
- 200WRMS @ 2 x 4 ohms
- 30Hz - 1kHz
- 86.6dB SPL @1W, 1m

CS-2351 Was $299.00

$249.00
SAVE $50.00

Vifa 12" Subwoofer
- 250WRMS @ 2 x 4 ohms
- 25Hz - 1kHz
- 87.2dB SPL @1W, 1m

CS-2353 Was $349.00

$299.00
SAVE $50.00

All Savings are based on Original RRP Limited Stock on sale items

Better, More Technical

To order call 1800 022 888

MEGA MAY

Don't forget Mother's Day - May 9th

Mega Security Clearance Sale - Up to 50% Off

Economy 4 Channel Multiplexing DVR

A combined multiplexer and digital video recorder with Ethernet port that allows remote access and control via a web browser. Features MPEG-4 compression, advanced motion recording, video loss detection, remote network record and back-up support. Supplied with a 250GB HD and can be expanded up to 400GB. See website for specifications. 340mm wide.

$299.00
SAVE $200.00

- Ethernet capability
- MPEG-4 compression
- 250GB HDD included

QV-3079 Was $499.00

Day/Night 470TVL Colour CCD Camera

Colour by day, black and white by night. This high-resolution CCD camera is perfect for use with infra red illuminators.

- 1/3" Sony Hi-Res SuperHAD CCD Sensor
- Auto Iris Control
- 470TVL resolution
- Minimum illumination: 0.2 lux
- Day / Night changeover level: 3 lux

QC-3301 Was $299.00

$229.00
SAVE $70.00

Also available:

Day/Night 520TVL Colour CCD Camera
Cat. QC-3307 Was $299.00 Now $219.00 Save $80.00

Day/Night 350TVL Colour CCD Camera
Cat. QC-3309 Was $149.00 Now $119.00 Save $30.00

Security Camera Clearance

Description	Cat No.	Was	Now	Save
Spare 2.4GHz Camera for QC-3258	QC-3259	$99.95	$69.00	$30.95
IP67 Pro Outdoor Colour Camera with Sony Super HAD CCD Sensor	QC-3381	$549.00	$399.00	$150.00
Dome Style Colour CCD Camera with Panasonic Sensor	QC-3498	$279.00	$179.00	$100.00
2.4 GHz Mini Wireless CMOS Camera Kit	QC-3569	$129.00	$99.00	$30.00
5.8GHz Wireless CMOS Camera with 4 Ch Receiver	QC-3570	$119.00	$99.00	$20.00
5.8GHz Wireless CMOS Camera	QC-3571	$79.00	$69.00	$10.00
5.8GHz Wireless CMOS Camera with IR Illuminator	QC-3573	$82.00	$69.00	$13.00
Mini Colour CCD Reversing Camera	QC-3727	$249.00	$179.00	$70.00
Flush Mount Colour CCD Reversing Camera	QC-3728	$199.00	$179.00	$20.00
Clip-On CCD Reversing Camera	QC-3729	$199.00	$179.00	$20.00
Vari-focal 480TVL Dome Camera	QC-3297	$299.00	$219.00	$80.00
Low Cost Colour Mini Dome Camera - Sharp Sensor	QC-3291	$89.00	$69.00	$20.00

Dome Style B&W CCD Camera

This quality dome housing is fitted with a 1/3" Samsung® CCD sensor, mounted on an adjustable bracket. The darkened dome improves security by preventing would-be thieves from seeing where the camera is pointed. Ideal for use in retail stores and reception areas etc. Requires 12VDC.

$55.00
SAVE $34.00

- 380 TVL
- 0.5 Lux Min
- 92° Lens angle

QC-3472 Was $89.00

Also available:
B&W CCD Camera in Metal Case with Audio
Cat. QC-3474 Was $89.00 Now $59.00 Save $30.00

550TVL IR Dome Camera

A high quality colour IR dome camera with 550TV line resolution and a 1/3" Sony HR sensor chip. The camera features a 3D gimble mount enabling the camera to be installed on the roof or wall. Requires a 12VDC regulated power supply.

- Min. illumination: 0.4 Lux / F 2.0 (Day), 0 Lux (IR on)
- Power consumption IR On: 480mA max,
- IR Off: 200mA max.
- Dimensions: 140(Dia) x 81.4(H)mm
- Power supply: 12VDC
- Recommended power supply: MP-3011

QC-8600 Was $299.00

$219.00
SAVE $80.00

B&W Underwater (1m) Day/Night CCD Camera

This camera features a water resistance rating to IP57 allowing it to be submerged underwater. This makes it ideal for aquariums or virtually any underwater surveillance application up to a maximum depth of 1 metre. The camera will operate down to 0-lux, courtesy of 12 infrared LEDs mounted behind a protective glass shield.

- Sensor: 1/3" CCD
- Connections: 12VDC/2.1mm, video BNC
- Lens: 3.6mm (92°)
- Dimensions: 65 (D) x 120 (L)mm

QC-3490 Was $99.00

Also available:
Colour IP57 Day/Night CCD Camera 330TVL
Cat. QC-3492 Was $249.00 Now $119.00 Save $130.00

$69.00
SAVE $30.00

Colour IP57 Day/Night CCD Camera 480TVL
Cat. QC-3495 Was $299.00 Now $199.00 Save $100.00

Colour CCD Dome Camera with Sony Sensor

A high quality colour CCD dome camera with 350TV line resolution and 1/3" Sony sensor chip. The camera features auto white-balance and shutter speeds from 1/50 to 1/100,000 of a second and is compact enough to be installed in the smallest of rooms or corridors. The camera is mounted inside a small dome making it ideal for security application where a visible deterrent is helpful.

- Requires a 12VDC regulated power supply. Use our MP3011-12VDC 300mA Regulated AC Adaptor.

QC-3318 Was $179.00

$89.00
SAVE $90.00

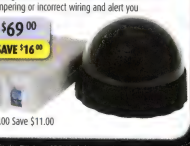
That's 50% Off

Colour Dome Camera Kit with 2-Wire Connection

A simple 2 wire combined arrangement for power and video make this system a snap to install. The system uses a CMOS image sensor with 350TV line resolution and will automatically sense signal cable tampering or incorrect wiring and alert you with a warning signal. Kit includes camera, signal processor, connecting cable, and mains adaptor.

QC-3264 Was $85.00

$69.00
SAVE $16.00



Also available:
Outdoor IR version (IP56 rated)
Cat. QC-3266 Was $100.00 Now $89.00 Save $11.00

Personal Mini Alarm with LED Torch

A personal alarm made from tough ABS construction with a 120dB siren to deter thieves and attackers. To activate simply pull the rip-cord to pull out the pin. Replace the pin to deactivate the alarm. Also includes a LED light. Great for travellers.

- 105-120dB
- Practical design
- Compact size
- Includes 3 x LR44 batteries
- Dimensions: 72(L) x 31(W) x 22(H)mm

LA-5183

$9.95

www.jaycar.com.au

All Savings are based on Original RRP
Limited Stock on sale items

Jaycar Electronics

AV Clearance Sale

HDMI 3 Port Switch

This system expander will allow you to hook up, convert and switch between a component video (YPbPr), DVI-Digital, and a HDMI signal to one HDMI v1.3 output. Audio is also combined with the video signal, so you can combine stereo audio or optical digital audio with your YPbPr video source and DVI-D can be combined with optical digital audio. Includes an IR remote control for ease of use, as well as the mains adaptor.

$139.00
SAVE $10.00

- Dimensions: 258(W) x 120(D) x 28(H)mm

AC-1684 Was $149.00

MP3 Player to Cassette Adaptor

Play your favourite MP3 tracks in any car cassette player or use it as an MP3 player.

- Supports SD, mini SD and MMC cards
- Remote cable 450mm long
- USB cable and cigarette lighter adaptor included
- 8 hours playing time from one charge

AR-1764 Was $44.95

$39.95
SAVE $5.00

HDMI Extender

The typical maximum range of a HDMI signal is just 12m at maximum - not very long if you are trying to send your high definition A/V signal from one end of the lounge room to the other. This HDMI extender equalises and boosts your HDMI signal so that you can run cable up to 50m long.

- Supports up to 1080p resolution
- Compatible with VGA, SVGA, XGA, SXGA, UXGA
- Automatic equalisation up to 1.6Gbps
- HDMI v1.3 compliant
- Dimensions: 50(L) x 28(W) x 18(H)mm

AC-1697 Was $39.95

$29.95
SAVE $10.00

Dual Channel AV Sender

Allows you to connect two AV sources, such as your TV, Hi-Fi sound system, video recorder, DVD player, set top box, or cable TV system, to the transmitter, share them around the house, and select either of them from the other room, without the hassle of running wires. A selector button on the receiver allows selection between the two connected devices.

AR-1838 Was $79.95

$69.95
SAVE $10.00

Additional Receivers With Remote Extender available separately Cat. AR-1839 Was $54.95 Now $37.95 Save $17.00

Great Gift Ideas For Mum

Kitchen Scales with Clock and Temp Display

Kitchen scales, clock and weather station all rolled into one. It weighs up to 3kg (6.6lb) in metric or imperial, then can be used as a wall clock that displays temperature and humidity as well. Funky orange design. Requires 3 x AAA batteries.

- Celsius and Fahrenheit display
- Kg or lb
- Size: 200(Dia) x 22(H)mm

Note: Dish not included

XC-0161 Was $44.95

$34.95
SAVE $10.00

Vacuum Bag Sealer

She can seal her goodies in the reusable bag and use the powerful pump to vacuum seal it. Ideal for freezing or food drying.

- 3 bags included
- Reduces plastic bag waste
- Requires 6 x AA batteries
- Measures: 270(L)mm

GH-1342 Was $24.95

$19.95
SAVE $5.00

Automatic IR Liquid Soap Dispenser

A functional and stylish addition to any kitchen or bathroom sink. It features a blinking LED to indicate operation, a large 410ml (14 ounce) liquid soap reservoir for fewer refills and a manual dispensing button to provide continuous soap flow for larger cleaning tasks. Just wave your dirty hands - no mess, no fuss, no germs!

- Requires 4 x AA batteries
- Dimensions: 90(W) x 130(D) x 200(H)mm

GH-1187

$24.95

Slimline LCD/Plasma Brackets

Projecting only 10mm from the wall, these ultra-slim brackets are very easy to install but will accommodate an LED, LCD or plasma TV up to 80kg. The spring-loaded cleats lock in position so the TV can't be accidentally knocked off. Two sizes available for 23-37" TVs or 32-60" TVs.

- Fits standard spacing wall studs
- Ultra-low profile

Slimline LCD/Plasma Bracket for 23 - 37", 45kg. Cat. CW-2821

$39.95

Slimline LCD/Plasma Bracket for 32 - 60", 80kg. Cat. CW-2823

$49.95

High Quality Lightweight Stereo Headphones

Ultra-lightweight stereo headphones that provide outstanding performance and comfort. Featuring high output drivers with neodymium magnets, they produce crystal clear sound with crisp highs and smooth bass response. Soft leatherette swivel ear pads, adjustable headset and 1.2m lead.

- Frequency response: 150Hz - 20kHz
- Weight: 80 grams

AA-2061

$24.95

Also available: **High Quality Full Cup Stereo Headphones** Cat. AA-2063 $34.95

Cat III Rated Banana Alligator Clip

Takes standard and fully insulated 4mm banana plugs and turns them into an alligator clip. CAT III rated. Sold as a pair, red and black.

PA-3696

$9.95

TV Accessories & AV Leads

TV Adaptors

75 ohm TV plug to F81 socket
- Right angle

Cat. PA-3673 $4.95

75 ohm plug to 75 ohm socket
- Right angle

Cat. PA-3679 $4.95

Right Angle HDMI Adaptors

Adapts HDMI plug to socket at right angles. Perfect for wall mounted TV applications. Gold plated connections. Two types available:

Right Angle Down
PA-3646 $12.95

Right Angle Up
PA-3648 $12.95

High Quality Concord Leads

RCA LEADS
- Video Lead RCA - RCA
- 0.5 metre

Cat. WQ-7221 $10.95

- 2 x RCA to 2 x RCA Plug Lead
- 0.5 metre

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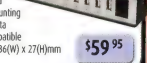

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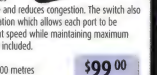

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YN-8087

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PRODUCT SHOWCASE

PowerShield Home Theatre Powerboard with the lot!

With powerboards available for under $3 these days, one which sells for $149 is going to need to be something extra special!

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For a start, it's the appearance – in superb "piano black" finish it's not something to hide away – it's something to show as a feature of your home theatre system!

With three "always on" and five slave 3-pin mains outlets (the slaves power up when a master device is turned on) you're going to save a lot of "standby" electricity. We're told that up to 10% of our power bills are from standby power.

But that's not unusual, lots of powerboards can do that. What is unusual is that any of your existing device infrared remote controls (eg TV, DVD, etc) will also control the powerboard. It will even power down automatically three minutes after the master device goes into standby mode.

It also has inbuilt surge, spike and lightning protection (144,000A or 3672 joules is the claim!) along with jacks for phone/fax protection (one line in, two lines out) and both F and standard aerial antenna sockets for TV antenna and cable antenna surge protection.

But wait, there's more: a large blue digital display reads the total power being used at any instant (in watts) through the slave outlets, so you can make a conscious effort to save power.

The device itself uses only 0.85W on standby.

The PowerShield Theatreguard is available from Altronics stores, resellers and via their website (Cat P8140).

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Tel: 1300 780 999 **Fax:** 1300 790 999
Website: www.altronics.com.au

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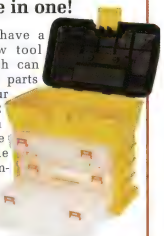


Jaycar have a great new tool box which can also hold parts in its four 233 x 122 x 32mm storage trays. The 13 tray compartments can be removed to fit larger items.

All the hinges and catches are the durable pintle type, not a flimsy bit of folded plastic that will snap after a week. The tool box has a generous 265 x 160 x 65 space and it's finished in a tasteful shade of industrial yellow and black.

Retail price is $14.95 (Cat HB6302), available from all Jaycar stores, resellers and their website. SC

Contact:
Jaycar Electronics
(All stores and web Techstore)
Tel: 1800 022 888
Website: www.jaycar.com.au

Avcomm's new tiny multiband receivers have Digital Signal Processing

They might be small (135 x 85 x 27mm) but these two new Tecsun multiband receivers pack some outstanding features, including DSP.

DSP offers the highest possible sensitivity, selectivity and provides a continuous display of received level and signal-to-noise ratio. It is particularly suited to those who desire broadcast band reception.

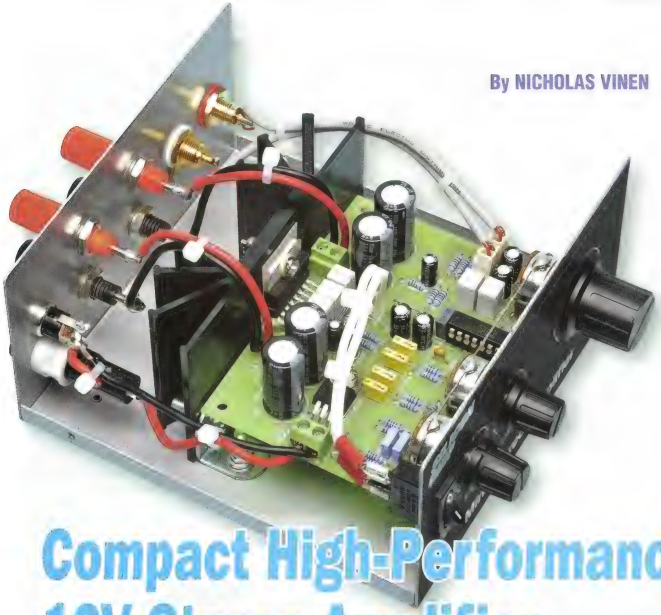
The Tecsun PL300 (left) covers 64.00MHz to 108.00MHz (FM – including the FM broadcast band) – and from 153KHz to 1710KHz (long wave and AM broadcast band) plus 3150KHz to 21950KHz in 1KHz steps. This model features a world-time dial and display. It normally retails for $89.00 but Silicon Chip readers who mention that they saw it in the magazine can get it for just $79 (May 2010 only).

The Tecsun PL310 receiver covers the same bands but offers several added features, including keyboard direct frequency entry and an external antenna socket while still offering DSP across all bands. The PL310 retails for $90.00

Both have earphone sockets (and earphones are included) and are powered by 3xAA batteries but the PL-310 includes a mini USB socket so can be powered via a computer or standard USB supply. Both also offer LCD clocks and frequency displays.

Contact:
Av-Comm Pty Ltd
24/9 Powells Road, Brookvale NSW 2100
Tel: (02) 9939 4377 **Fax:** (02) 9939 4376
Website: www.avcomm.com.au

By NICHOLAS VINEN



Compact High-Performance 12V Stereo Amplifier

Amplifiers which run from 12V DC generally don't put out much power and they are usually not hifi as well. But this little stereo amplifier ticks the power and low distortion boxes. With a 14.4V supply, it will deliver 20 watts per channel into 4-ohm loads at clipping while harmonic distortion at lower power levels is typically less than 0.03%.

THIS IS AN IDEAL project for anyone wanting a compact stereo amplifier that can run from a 12V battery. It could be just the ticket for buskers who want a small but gutsy amplifier which will run from an SLA battery or it could used anywhere that 12V DC is available – in cars, recreational vehicles, remote houses with 12V DC power or where ever.

Because it runs from DC, it will be an ideal beginner's or schoolie's project, with no 240VAC power supply to worry about. You can run it from a 12V battery or a DC plugpack. But while it may be compact and simple to build, there is no need to apologise for "just average" performance. In listening tests from a range of compact discs, we were very impressed with the sound quality.

Long-time readers might recall that we presented a similar 12V power amplifier design back in May 2001. It was a similar configuration to this one but it is now completely over-shadowed by the much lower distortion and greatly improved signal-to-noise ratio of this new design. In fact, let's be honest: the previous unit is not a patch on this new design. It used two TDA1519A ICs which resulted in distortion figures above 1% virtually across the board and a signal-to-noise ratio of only -69dB unweighted.

However, by using the TDA7377 power amplifier IC and making some other improvements, the THD (total harmonic distortion) of the new design is about 50 times better than the older unit (see performance graphs for details). The bottom line is that the THD under typical conditions is around just 0.03% or less. It is also able to deliver more output power due to the improved output transistors in the new power amplifier IC.

In addition, its idle power consumption is low – not much more than 1W. As a result, if you don't push it too hard it will run cool and won't drain the battery too quickly. And because the IC has self-protection circuitry, it's just about indestructible. It will self-limit or shut down if it overheats and the outputs are deactivated if they are shorted.

It may only be small but the 12V Mini Stereo Amplifier puts out up to 20W per channel into 4Ω loads at low distortion. It uses just two ICs and is very easy to assemble.

Obtaining enough power

With a 12V supply, the largest voltage swing a conventional solid-state power amplifier can generate is ±6V. This results in a meagre 4.5W RMS into 4Ω and 2.25W RMS into 8Ω, without considering losses in the output transistors. Even if the DC supply is around 14.4V (the maximum that can normally be expected from a 12V car battery), that only brings the power figures up to 6.48W and 3.24W for 4Ω and 8Ω loads respectively – still not really enough.

There are three common solutions to this problem. The first is to boost the supply voltage using a switchmode DC converter. This greatly increases the cost and complexity of the amplifier but it is one way of getting a lot of power from a 12V supply. However, we wanted to keep this project simple and that rules out this technique.

There are variations on the boosting method, such as the class H architecture used in the TDA1562Q IC featured in the Portapal PA Amplifier (Silicon Chip, February 2003). It is able to achieve 40W/channel but with >0.1% THD. In that case, the amplifier output itself provides the switching for a charge pump.

The second method is to lower the speaker impedance. Some car speakers have an impedance as low as 2Ω, which allows twice as much power to be delivered at the same supply voltage. However, we don't want to restrict this amplifier to 2Ω loudspeakers.

The remaining solution is to use bridge mode, also known as Bridge-Tied Load (BTL). It requires two amplifier circuits per channel. The TDA-7377 IC is ideal for this purpose – it contains four amplifiers in a single package and is intended for a bridged stereo configuration.

In the TDA7377, two of the four amplifier circuits have inverting inputs, so all we need to do is to feed the same signal to one of each type and the outputs will swing in opposite directions – when one voltage goes up the other will go down and vice versa.

Instead of connecting the speakers between the amplifier output and ground, we connect them between the two outputs. This doubles the voltage across the speaker and multiplies the maximum power delivered by four ($P = V^2/R$). It also eliminates the AC-coupling capacitor at the output, which is needed with a standard single supply amplifier.

Practically speaking, virtually any 4Ω or 8Ω speaker is suitable for use with this amplifier; the more efficient, the better. Avoid anything less than 4Ω, as that would be asking each amplifier circuit to drive a load under 2Ω, which the IC is not rated for.

Circuit description

Fig.3 shows the full circuit. As can be seen, it's based on the aforementioned TDA7377V monolithic stereo BTL amplifier (IC2) plus a TL074 quad FET-input op amp package (IC1). The latter provides the tone control stages in both channels.

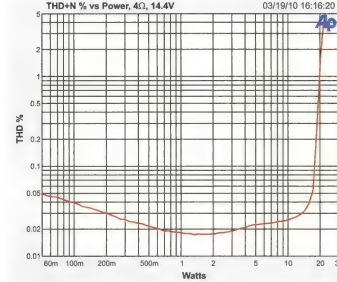


Fig.1: THD+N vs output power at 4Ω (one channel driven only). The supply is 14.4V and the measurement bandwidth is 20Hz-22kHz. The distortion increase below 1W is due to noise.

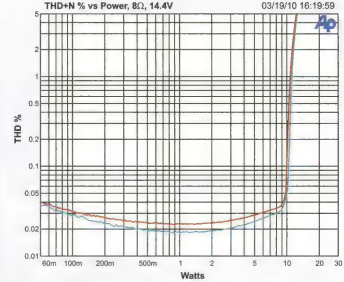


Fig.2: THD+N vs output power at 8Ω with both channels driven. The supply is 14.4V and the measurement bandwidth is 20Hz-22kHz. The disparity between the channels is primarily due to tone control pot tracking errors.

As shown, the input signals are fed via 4.7µF non-polarised capacitors to a 10kΩ dual-gang potentiometer (VR1) which serves as the volume control. From there, the signals are AC-coupled via 470nF capacitors to op amps IC1a & IC1b. These act as unity-gain buffer stages to provide a low source impedance for the following Baxandall tone control stages based on IC1c & IC1d.

In operation, IC1c & IC1d and their associated potentiometers (VR2 & VR3) provide bass and treble boost of ±15dB, with a centre frequency of 700Hz. The frequency response is very flat when the pots are centred (see Fig.11).

To understand how the tone control stages work, let's consider the bass and treble sections separately. We'll concentrate on the bass sections first but will initially ignore the 10nF capacitors. This leaves us with an inverting amplifier (IC1c or IC1d), where the resistors (including the pots) form the feedback network and thus control the gain. With the bass pot turned all the way clockwise, the gain is set at 122kΩ/22kΩ or about 5.5. If it is turned in the opposite direction, the gain is 22kΩ/122kΩ or 0.18.

Adding the 10nF capacitors across VR2a & VR2b adds a low-pass filter to each gain network, so that turning the knob affects low frequencies more than high frequencies. As a result, we can adjust the gain of the bass and hence achieve bass boost/cut.

The treble section (VR3a & VR3b) works similarly except that the capacitors (4.7nF in this case) are in series with the resistors, thus forming a high-pass filter instead.

The 10pF capacitors on the inverting inputs of IC1c & IC1d reduce their gain at high frequencies, thereby preventing oscillation in case there is RF pick-up in the filter network. Similarly, the 10Ω resistors at the outputs of IC1c & IC1d attenuate any RF signals which may make it through before they go into the power amplifier (IC2).

Power amplifier

Only a few external components are required by the single TDA7377V IC (IC1). It's very clever – not only does it contain the four low-distortion amplifiers we need to drive stereo speakers in BTL configuration but it has virtually rail-to-rail swing on the outputs and is inherently stable with a fixed 26dB gain (see the separate article in this issue for more details on how the TDA7377V works).

We have used its standby pin (pin 7) to switch the amplifier on and off. This avoids having high current passing through on/off switch S1. In fact, S1 only switches the power to pin 7 of IC2 and to the quad op amp IC1. Hence the power supply and IC1 remain energised as long as the supply voltage is present but only the capacitor leakage and standby current are drawn, a total of around 100µA. Switching the amplifier on raises the quiescent (no signal) current to around 100mA.

As soon as switch S1 is turned on, the 100µF filter capacitor is charged via diode D1. The standby pin (pin 7) has a low-pass filter consisting of a 22kΩ resistor and 1µF capacitor so that the power amplifier is not enabled until the op amp is on. This avoids turn-on thumps.

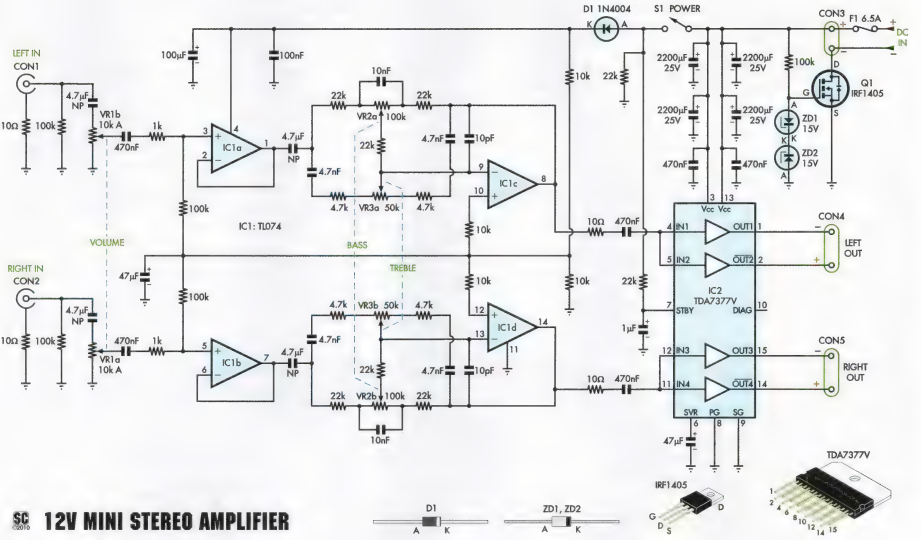
Similarly, when you switch S1 off, the 22kΩ resistor at the anode of diode D1 pulls down the standby pin voltage, turning the power amplifier IC off almost immediately. This avoids switch-off thumps from the loudspeakers.

Reverse polarity protection

The main power supply components are the four 2200µF 25V electrolytic capacitors plus two 470nF MKT capacitors in parallel for high-frequency filtering. Mosfet Q1 provides reverse polarity protection for this section.

Although the TDA7377 IC can withstand negative supply voltages, the electrolytic capacitors cannot. In the May 2001 design, a 3A diode was placed across the supply rails so that it would conduct and blow the fuse if the supply polarity was accidentally reversed. In this circuit, however, we have connected an IRF1405 Mosfet in series with the supply ground lead.

In essence, the Mosfet acts like a diode with a very low forward volt-



12V MINI STEREO AMPLIFIER

Fig.3: the complete circuit is based on a TL074 quad FET-input op amp (IC1) and a TDA7377V quad power amplifier (IC2). IC1a-IC1d and their associated stereo potentiometers (VR2-VR3) form a Baxandall tone control circuit and this drives IC2 which is wired in bridged stereo mode. Mosfet Q1 provides reverse polarity protection.

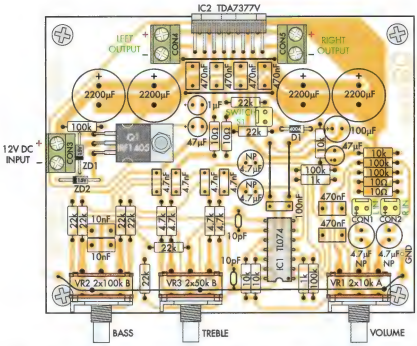


Fig.4: follow this layout diagram to build the PC board. Make sure that all polarised parts are correctly oriented and don't get the pots mixed up.

This view shows the completed prototype. The pot bodies are connected together using a length of tinned copper wire which loops across them and is terminated in pads on either side of the board.

age, typically less than 25mV at 5A (we measured 8.7mV at 2.5A). This compares with around 1V at 5A for a standard rectifier diode. This means that the amplifier can deliver significantly more power, about 15% more, in fact, than if a standard diode had been used.

Power source

The maximum current consumption depends on the speaker impedance and how far up you turn the volume. As a rough guide, full power with a 14.4V supply and 8Ω speakers requires at least 3A. For 4Ω speakers, the current consumption can exceed 6A.

At a minimum, use a 7.2Ah SLA battery for 8Ω speakers or a 12Ah SLA for 4Ω. They should last 2-24 hours depending on how hard you're driving the amplifier (larger batteries will last longer).

You can charge the battery while using the amplifier, although this may slightly prejudice the sound quality due to the supply ripple that charging introduces. Power supply rejection is >50dB at 300Hz and thanks to the large supply bypass capacitors, the additional noise should be kept to a low level.

If you want to run the amplifier from a mains power supply, both linear and switchmode types are suitable. A 6A linear supply is likely to be large and expensive so switchmode is probably the way to go. A higher supply voltage (ie, up to 16V) will give more power.

The absolute maximum operating voltage is 18V, so make sure whatever you use can never exceed that.

Construction

All the circuitry, including the potentiometers for the volume and tone controls, is mounted on a PC board measuring 97 x 78mm and coded 01104101. This is mounted in a compact metal case with an aluminium base and steel lid.

Fig.4 shows the parts layout on the PC board. Start by checking the board for defects, such as shorts or breaks in the copper tracks and undrilled holes. If it's OK, start the assembly by installing the four wire links using 0.71mm tinned copper wire. Make sure they are straight and flat before soldering, since some of the links pass near exposed component legs.

Next, install the fixed value resistors. It's a good idea to check each value with a DMM, as the colour codes can be notoriously hard to read.

After that, solder in the two zener diodes. They are identical but make sure that you get their orientation correct.

Once the zeners are in, bend the

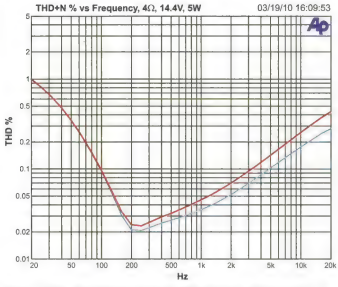


Fig.5: THD+N vs frequency for 5W into 4Ω. The supply is 14.4V and the measurement bandwidth is <10Hz-80kHz. The reading at 1kHz is slightly higher than in Fig.1 due to the wider measurement bandwidth.

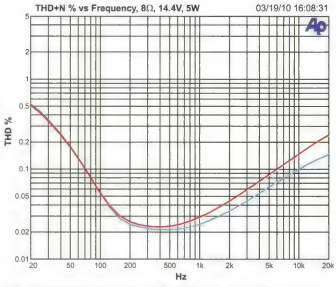


Fig.6: THD+N vs frequency for 5W into 8Ω. The supply is 14.4V and the measurement bandwidth is <10Hz-80kHz. The reading at 1kHz is slightly higher than in Fig.2 due to the wider measurement bandwidth.

Mosfet's leads down at right angles about 5mm from its tab using small pliers. That done, insert its leads into the PC board and check that its mounting hole lines up. Adjust the leads if necessary, then secure the tab to the PC board using an M3 x 6mm machine screw, spring washer and nut. Once it is firmly in place and cannot move, solder and trim the three leads.

Next, install the three terminal blocks. Push them all the way down so that they sit flush with the board and check that they are correctly oriented before soldering their pins. The three polarised polarised headers can then be installed, again taking care with their orientation.

Follow with the MKT capacitors and the two ceramic types. The polarity doesn't matter here but don't get the values mixed up. The four bipolar electrolytic capacitors can then be installed, followed by the four small polarised electrolytics but don't install the larger 2200µF units just yet.

Next, install the TL074 IC, making sure it goes in the correct way around. We used a socket in our prototype but there's no reason why it cannot be directly soldered to the PC board.

Installing the TDA7377

It's now time to install the TDA7377V. You must do this slowly and carefully since it's difficult to remove if it's misaligned.

Start by gently inserting its leads through the board, taking care not to bend any of them. You may need to adjust them using needle-nose pliers if they have been bent during transport, so that they line up properly.

Once the pins have been pushed all the way down, place the metal tab of the IC on a flat, horizontal surface with the PC board vertical. Hold the IC down against the surface and adjust the angle of the board so that they are exactly at right angles. That done, check that the pins are all still properly inserted and that the package is parallel with the edge of the board.

When it is all straight, solder a couple of leads and recheck its orientation before finishing the job.

The four 2200µF electrolytic capacitors can now be installed. Make sure that each of these sits flush against the PC board and is oriented correctly.

Cutting the pot shafts

Before fitting the potentiometers (VR1-VR3), it's necessary to cut their

Table 2: Capacitor Codes

Value	µF Value	IEC Code	EIA Code
470nF	0.47µF	470n	474
100nF	0.1µF	100n	104
10nF	0.01µF	10n	103
4.7nF	.0047µF	4n7	472
10pF	NA	10p	10

Table 1: Resistor Colour Codes

❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	5	100kΩ	brown black yellow brown	brown black black orange brown
❑	8	22kΩ	red red orange brown	red red black red brown
❑	4	10kΩ	brown black orange brown	brown black black red brown
❑	4	4.7kΩ	yellow violet red brown	yellow violet black brown brown
❑	2	1kΩ	brown black red brown	brown black black brown brown
❑	4	10Ω	brown black black brown	brown black black gold brown

Follow this photo and the text to complete the wiring inside the case. Note the use of shielded cable to connect the RCA input sockets.

shafts to length so that the "D"-shaped sections (ie, the flat sections) are about 10mm long. This is done by clamping the end of each shaft in a vice and then cutting it with a hacksaw. Deburr the ends when you have finished, so that the knobs can later be fitted.

VR1-VR3 can now be installed on the board. They each have a different value, so be sure to mount each one in the correct location.

Earthing the pot bodies

To prevent noise pickup, it's necessary to earth the bodies of the pots. This is done using a length of tinned copper wire which loops across the top of the pots and is terminated at both ends to pads on the PC board.

To install this wire, first solder one end to the pad immediately to the right of the volume control. That done, stretch the wire across the tops of the three pots and feed the free end into the pad to the left of the bass pot. Finally, pull the wire down tight and solder it in position, then solder the wire to the top of each pot body.

Note that it will be necessary to scrape away the passivation material on each pot body in order for the solder to take. You will also need to use a hotter-than-normal soldering iron in order to heat the pot bodies sufficiently for soldering.

In practice, the pot bodies will later all be in contact with the bare metal of the case, so it should not be necessary to connect the GND pad on the PC board to the case itself. **However, if you elect to house the board in a plastic case, it will be necessary to connect the GND pad to the ground (-) terminal of CON3.**

The PC board assembly can now be completed by attaching an M3 x 12mm spacer to each corner, secured by M3 x 15mm machine screws. That done, thread M3 x 9mm spacers over each end so that you effectively finish up with four 21mm spacers. Note: the spacers at the rear of the board are later removed when it is attached to the heatsink.

Initial checks

If you have a bench supply, set it to 12V with a current limit of 200mA. Otherwise, use a 12V plugpack or similar supply – if possible, one which is too small to provide much current.

First, connect your DC supply to the power block (CON3), with a DMM wired in series and set to read amps. Now switch the supply on and check the current reading. With no power switch attached, the current should be negligible (<1mA) and the DMM will probably read 0 (once the 2200µF capacitors have charged).

If it reads more than a few milliamps, switch off and check the board for mistakes.

Now short the switch header pins (ie, for S1) together using a piece of wire. The current should now increase to around 100mA and possibly as high as 160mA. If you remove this short, the reading should drop back to 0mA within a second or so.

If you have made a mistake with the Mosfet or zeners, it's possible no current will flow at all. If that happens, check that area of the board. It could also be a problem with the standby RC filter components (22kΩ and 1µF).

Drilling the case

Fig.7 shows the drilling details for the front and rear panels of the case. This can either be copied and used as a template or you can download a PDF file from the SILICON CHIP website, print it out and use that instead.

Start by attaching the front panel template section to the case. Once that's done, centre-punch the location of each hole, then remove the template and drill a small pilot (eg, 2mm) hole at each location. Before going further, place the board assembly in the case and check that the three righthand holes line up correctly with the centres of the pot shafts.

Once you are satisfied that everything is correct, drill the three potentiometer holes to 6.5mm, then check that the pot shafts (included the threaded portions) go all the way through). Enlarge the holes if necessary using a tapered reamer until it fits correctly.

The switch cutout is made by first pilot-drilling the two marked posi-

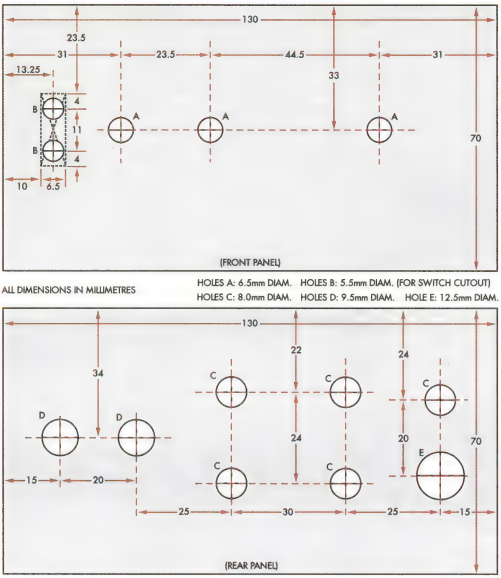


Fig.7: this diagram shows the drilling templates for the front and rear panels. Centre-punch each hole position and drill small pilot holes before carefully enlarging them to size using progressively larger drills and a tapered reamer.

tions, then enlarging them to 5.5mm and drilling a third hole between them. The centre piece can then be knocked out and a small flat file used to gradually enlarge the cutout to the marked rectangular outline.

Slowly enlarge it in each direction until the switch snaps into place and is locked in by its plastic tabs. It will take a good 10-15 minutes of patient filing, so take it slowly and make sure you don't make the hole too large or crooked.

Installing the PC board

In order to later secure the PC board, it's necessary to drill mounting holes in the base of the case for the front (but not the rear) spacers. The two holes should each be marked on the underside of the case and are positioned 6mm in from the front panel and 21mm in from the sides. Drill them to 3mm then slide the board into position and fit the mounting screws.

Don't worry about securing the pots to the front panel at this stage —that step comes later. For the time being, just check that everything lines up correctly, then remove the board and power switch so that the rear panel can be drilled.

Rear panel drilling

Eight holes have to be drilled in the rear panel – two for the insulated RCA input sockets (D), four for the loudspeaker terminals (C), one for the DC power socket (C) and one for the fuse (E).

Begin by securing the drilling template accurately in position (use tape), then centre-punch each hole location, and drill small pilot holes. The template can then be removed and the holes enlarged to the sizes indicated using drills and a tapered reamer (ie, 8mm for the binding posts and DC connector, 9.5mm for the RCA sockets and 13-15mm for the fuseholder, depending on the exact type).

Use an oversize drill to deburr the holes, then install the rear panel hardware as shown in the photos. Make sure all the nuts are done up tightly so the components can't rotate. By the way, insulated RCA input sockets

Using A Mosfet As A Diode

In this project we have used a Mosfet instead of a diode for reverse polarity protection, for the reasons explained in the article.

Fig.8 shows how an N-channel Mosfet is typically used for motor control, lamp flashing or any other task where a high current DC electronic switch is required. Because a Mosfet's source is generally connected to the substrate, a parasitic diode known as the "body diode" is present. This is shown in the symbol and it cannot be avoided.

Because its source is connected to ground, Q1 is on whenever the gate voltage is above the Mosfet's on-threshold (usually 2-4V). The body diode is reverse biased and does not conduct unless the load is inductive and switch-off causes a large enough positive voltage spike to trigger reverse breakdown (avalanche).

What we want to do, though, is use a Mosfet to prevent current flow if V_{CC} becomes negative. In the case of Fig.8, if this were to happen, the body diode would conduct and it would be impossible for the Mosfet to provide reverse polarity protection. Hence, we must reverse the Mosfet and connect it so that the source is positive with respect to the drain, as shown in Fig.9.

Note that the body diode is now forward biased when V_{CC} is positive. If we also bias the Mosfet on, all of the current will flow through the channel (ie, source to drain) instead. The channel path will have a much lower voltage drop than the body diode.

We achieve this by connecting a resistor between the supply input and the gate. When the supply voltage is positive, the Mosfet is turned on and if it becomes negative it will be turned off and of course, the body diode will be reverse-biased!

Because the source is no longer connected to ground it may seem that we can no longer turn the Mosfet on. In fact, the source is pulled to ground via the body diode.

The final refinement adds two back-to-back zener diodes between the gate and source terminals. They are included to prevent a supply voltage spike of more than ±20V from destroying the Mosfet.

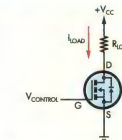


Fig.8: using a Mosfet as a switch (typical connection).

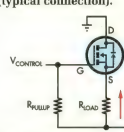


Fig.9: using a Mosfet as an active rectifier.

are mandatory if you want to get low distortion.

Pay attention to the orientation of the holes in the binding posts. The upper two (red) should have the holes vertical, while the lower two (black) should be orientated with the holes 30-45° from vertical so that you can insert the speaker leads from the side.

Attaching the heatsink

The specified heatsink is a 55 x 105mm "fan" type. It is quite heavy, so it will need to be attached to the base of the case using two right-angle steel brackets (obtained from Bunnings).

To do this, stand the heatsink vertically on a flat surface and place a bracket flush against the flat side at one end. Mark the centre of the mounting hole, then repeat this procedure at the other end. The two holes are then centre-punched and drilled to 4mm. Remove any swarf from around the holes using an oversize drill, then attach the brackets using two M4 x 10mm machine screws, spring washers and nuts.

Now remove the rear spacers from the PC board, install it in the case and slide the heatsink up to it so that it sits flush against IC2's metal tab. Check that the heatsink is correctly centred, then mark the mounting holes for the heatsink brackets on the bottom of the case. The heatsink and PC board are then removed and the marked locations drilled to 4mm.

The next step is to drill a mounting hole in the heatsink for IC2's metal tab. That's done by first reinstalling the PC board in the case and securing the heatsink to the base using two M4 x 10mm machine screws and nuts. It's then just a matter of marking the hole location, then removing the heatsink, centre-punching the marked location and drilling to 3mm.

Now use an oversize drill to carefully deburr the mounting hole. **This step is most important — if there's any metal swarf around the hole, it could punch through the insulating washer that's used to electrically isolate IC2's tab from the heatsink and create a short circuit.** Basically, it's just a matter of checking that the mounting area is perfectly smooth by running your finger over the hole.

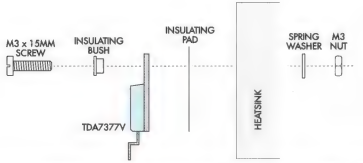


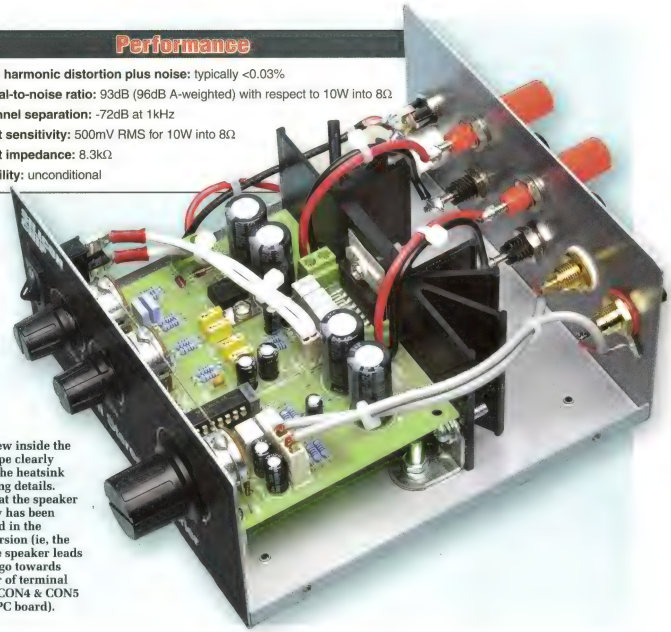
Fig.10: this diagram shows how the TDA7377V amplifier IC is attached to the heatsink. It must be electrically isolated from the heatsink using an insulating bush and pad.

Attaching IC2 to the heatsink

IC2's tab must be electrically iso-

Performance

Total harmonic distortion plus noise: typically <0.03%
Signal-to-noise ratio: 93dB (96dB A-weighted) with respect to 10W into 8Ω
Channel separation: -72dB at 1kHz
Input sensitivity: 500mV RMS for 10W into 8Ω
Input impedance: 8.3kΩ
Stability: unconditional



This view inside the prototype clearly shows the heatsink mounting details. Note that the speaker polarity has been reversed in the final version (ie, the positive speaker leads should go towards the rear of terminal blocks CON4 & CON5 on the PC board).

lated from the heatsink using an insulating bush and washer – see Fig.10. It's just a matter of fitting the heatsink back in the chassis, then attaching IC2's tab as shown. It's secured using an M3 x 15mm machine screw, spring washer and nut. Do the screw up firmly to ensure good thermal contact, then use your multimeter (set to a low ohms range) to confirm that IC2's tab is correctly isolated from the heatsink.

By the way, if you use a mica washer rather than a thermal insulating pad, be sure to smear both sides of the washer with thermal grease before bolting the tab down.

Front panel

A front panel for the specified case can be downloaded from the SILICON CHIP website (as a PDF file) and printed out on a colour printer. It's attached using double-side tape and this should be done with the PC board and heatsink assembly out of the case. You will also have to temporarily remove the rocker switch if it's in place.

Once the front panel is in position, cover it with some wide strips of adhesive tape, then cut out the holes for the switch and pot shafts using a sharp hobby knife. The adhesive tape covering will protect the label from scratches and finger marks and will provide a durable finish.

The PC board and heatsink assembly can now be permanently installed in the chassis. Before sliding it in, fit a nut onto the threaded boss of each pot and wind it all the way up to the pot body. That done, place the assembly in the case and secure it via the heatsink brackets and the screws that go into the front spacers.

Now wind the pot nuts forward until they contact the rear of the front panel, then fit three more nuts to the pots from the front. The six pot nuts can now all be tightened to lock the pots firmly in place and prevent the front panel from flexing. Once they are secure, fit the knobs and reinstall the rocker switch.

Chassis wiring

All that's left is the chassis wiring. First, cut a short length of red heavy-duty hook-up wire, strip the ends and solder it between the centre pin of the DC socket and the middle tab of the

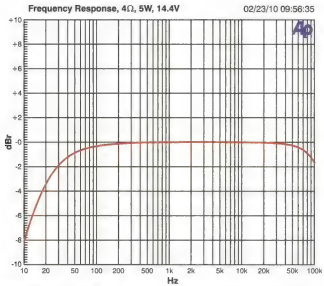


Fig.11: this shows the amplifier's frequency response for a 4Ω load with the tone controls centred. The -3dB point is around 25Hz. This is purposefully a little high to reduce the chance of "motor-boating" with a sagging supply voltage under load.

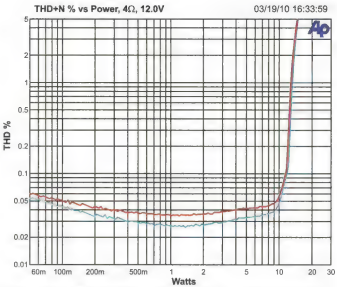


Fig.12: this graph of THD+N vs power is similar to that shown in Fig.1 except that the amplifier is powered from a 12V 4A switchmode supply. As you can see, performance doesn't suffer much except that full power output is reduced due to the lower supply voltage.

fuseholder. A 70mm length of red wire is then run from the end fuseholder tab to the +12V input terminal on the board (ie, at CON3).

Now connect the two remaining tabs on the DC socket together and run a 90mm length of black heavy-duty wire to the ground (-) terminal of CON3. In fact, the easiest way to do this is to strip the insulation from the hook-up wire back at least 15mm and wrap the wire around both these tabs before flowing solder over it. Because one of the tabs goes to the metal thread of the DC socket, this connects the negative rail to the case and improves the shielding.

Next, connect the speaker outputs, again using heavy-duty red and black hook-up wire (see photos). These leads run from CON4 & CON5 to the binding post terminals on the rear panel and should be made long enough so that they don't touch the heatsink.

Note that we've reversed the output terminal polarity compared to our prototype to compensate for the inverting preamplifier stage. Ultimately, though, it doesn't matter greatly, as long as both pairs of binding posts are connected the same way around (ie, the loudspeakers are not in anti-phase).

The power switch wiring is next. This can be run using two 95mm lengths of medium-duty hook-up wire. Begin by stripping about 8mm from one end of each wire and crimping them to two polarised header pins using pliers. Once you have crimped them, flow some solder into each junction so that it can't come apart.

After soldering, insert the two pins into one of the plastic header blocks then strip about 5mm from the other ends of the wires. These ends are then attached to 4.8mm female spade connectors (a ratcheting crimper will do the best job) which are then pushed onto the switch terminals.

Alternatively, solder the wires directly to the switch terminals if that's what you prefer but be careful not to overheat and damage the plastic switch body.

Wiring the RCA sockets

All that remains is the wiring to the RCA input sockets. These are connected using two lengths of shielded cable which run back to two polarised pin headers situated behind the volume control.

Begin by cutting two 150mm sections of shielded cable, strip 20mm of insulation from each end and twist the copper shield wires together. Then strip 5mm of insulation from the inner wires.

At one end, tin the shield and inner wires, then crimp them into polarised header pins and flow solder into the crimp pin so it can't come apart. Note that it's necessary to twist the shield wires tightly before soldering them, so that they fit into the header pins.

After soldering, insert the pins into

Connecting The GND Terminal

If you build the unit into the specified metal case, then it will not be necessary to connect the GND terminal to the case. That's because the circuit earth is connected to the case via the DC power socket, while the pot bodies are earthed to the case via the nuts used to secure them.

In fact, if you do connect the GND pad to the case under these circumstances, you could get an earth loop.

Conversely, if you elect to house the board in a plastic case, then it will be necessary to connect the GND pad to the ground (-) terminal of CON3. Alternatively, it can be connected to the negative terminal of the DC socket.

Similarly, if the pots are not directly secured to a metal chassis (ie, you don't fit the nuts), then the GND terminal should be connected to metalwork. You can do this by securing a solder lug to the base of the case and then running a short lead between it and the GND pad on the board.

the two remaining plastic header blocks. In each case, the inner wire of the shielded cable must go to the "+" side of the header block (see Fig.4). This means that when the headers are plugged in, the inner wire of each header must be to the left, as viewed from the front of the PC board.

The shield leads must be to the right, so that they connect to the earth pattern of the PC board when the headers are plugged in.

The other ends of the shielded leads can then be soldered to the RCA sockets. In each case, the inner lead goes to the centre terminal of the socket, while the shield wire is soldered to the solder tab.

As stated above, it's necessary to use insulated RCA sockets for the inputs. After connecting them, it's a good idea to check that neither RCA socket surround is shorted to the case (if they are, the performance will suffer). You can do this by using your multimeter to check for continuity between the outside metal surround of each RCA socket and the case. You should get an open circuit reading for both sockets.

If the meter does indicate a short, check that the shield wires are not touching the case at the metal tabs. If they are, just bend the tabs forward slightly until the short is cleared.

The assembly can now be completed by plugging the other ends of the shielded leads into the headers on the PC board. Don't get them mixed up – the left input (white socket) should go to the header on the left side of the PC board and vice versa.

Once the wiring is complete, use some cable ties to secure the various leads as shown in the photos. This not only keeps them looking tidy but will also prevent them from coming adrift.

That's it—construction is complete.

Final testing

Now for a final test. Install the 6.5A fuse into the fuseholder and connect a signal source (eg, a CD player) and a pair of speakers. Be sure to connect the speakers in phase and don't cross-wire the leads.

Now turn the volume knob all the way down, switch on and slowly turn the volume up. If you hear audio loud and clear then all is well! If not, switch off immediately and check the chassis wiring carefully. If there's a problem, it's a good idea to first measure the voltage across the power terminal block, to make sure power is actually reaching the board.

If that doesn't solve the problem, you'll need to recheck the component placement and orientation, as well as the solder joints. If the fuse blows, then you likely have a short circuit in your chassis wiring, because the earlier tests on the board would have shown up any shorts on the board itself.

Assuming all is well, put on your favourite CD and enjoy the sound! SC

Parts List

1 vented aluminium case (Jaycar HB-5444)
1 PC board, code 01104101, 97 x 78mm
1 55mm "fan"- type heatsink (Jaycar HH-8570, Altronics H-0250)
1 SPST mini rocker switch (Jaycar SK-0975, Altronics S-3202/S-3247)
2 4.8mm female spade lugs
2 small steel brackets (Bunnings RAB020)
4 M4 x 10mm machine screws
4 M4 nuts
4 M4 spring washers
1 2.1mm I.D. chassis-mount DC socket (Jaycar PS-0522, Altronics P-0622)
1 low-voltage M205 chassis-mount fuseholder (Jaycar SZ-2020, Altronics S-5992)
1 M205 6.5A fast-blow fuse
2 red insulated binding posts (Jaycar PT-0453, Altronics P-9252)
2 black insulated binding posts (Jaycar PT-0454, Altronics P-9254)
1 red insulated RCA socket (Jaycar PS-0276, Altronics P-0218)
1 white insulated RCA Socket (Jaycar PS-0278, Altronics P-0220 [Black])
2 16mm knobs (Jaycar HK-7762, Altronics H6040)
1 24mm knob (Jaycar HK-7764, Altronics H-6044)
3 2-pin terminal blocks (5.08mm spacing)
3 2-pin polarised headers (2.54mm spacing)
3 2-pin polarised header connectors (2.54mm spacing)
1 TO-218 mica or silicone insulating washer (with bush)
5 M3 x 6mm machine screws
1 M3 x 10mm machine screw
4 M3 x 15mm machine screws
2 M3 spring washers
2 M3 nuts
4 M3 x 12mm tapped Nylon spacers
4 M3 x 9mm tapped Nylon spacers
1 500mm length of red heavy-duty hook-up wire
1 500mm length of black heavy-duty hook-up wire
1 300mm length of medium-duty hook-up wire
1 400mm length of single-core shielded cable
1 300mm length of 0.71mm tinned copper wire
Heatsink compound (if using a mica insulating washer)
8 100mm cable ties
3 additional nuts for pots

Potentiometers

1 100kΩ linear dual gang 16mm potentiometer (VR2 – B100k)
1 50kΩ linear dual gang 16mm potentiometer (VR3 – B50k)
1 10kΩ log dual gang 16mm potentiometer (VR1 – A10k)

Semiconductors

1 TL074 quad op amp (IC1)
1 TDA7377V quad power amplifier (IC2) (available from Futurlec)
1 IRF1405 MOSFET (Q1)
2 15V 1W zener diodes (ZD1,ZD2)
1 1N4004 diode (D1)

Capacitors

4 2200μF 25V electrolytic
1 100μF 25V electrolytic
2 47μF 16V electrolytic
4 4.7μF non-polar (NP) electrolytic
1 1μF 25V electrolytic
6 470nF MKT
1 100nF MKT
2 10nF MKT
4 4.7nF MKT
2 10pF ceramic

Resistors (0.25W, 1%)

5 100kΩ	4 4.7kΩ
8 22kΩ	2 1kΩ
4 10kΩ	4 10Ω

By NICHOLAS VINEN

Low-Power Car/Bike USB Charger

Looking for an efficient USB charger that can operate from a 12V car battery? This unit functions at up to 89% efficiency and can charge USB devices at currents up to 525mA. Best of all, it won't flatten the battery if it's left permanently connected, as long as you remember to unplug the USB device.

THERE ARE LOTS of USB chargers on the market but this device has two stand-out features: high efficiency and low standby current. In fact, its standby current is just 160µA, a figure that's well below the self-discharge current of most lead-acid batteries.

This means that you can leave the device permanently connected and it will not cause that battery to go flat (or at least, not much faster than it would of its own accord).

Why is this useful? Well, in September 2009's "Ask SILICON CHIP" section, D. E. of Ainslie, ACT asked if it was possible to connect a 12V-to-5V USB charger directly to the battery on a motorbike. His reason for wanting to do this is that doing anything else might void the warranty. Our reply was that it is possible but that it would need to have a quiescent current (I_Q) of less than 1mA to avoid draining the battery between uses.

While USB car chargers are cheap and plentiful, finding one with a low enough quiescent current for permanent battery attachment is difficult. Even those marketed as "low idle power" devices don't specify how much current they draw on standby.

We tested a regular charger and found that it consumed 13mA with no load. Like many others, it has an integrated power LED and that would contribute significantly to the standby current consumption. However, since the cigarette lighter socket is only powered when the engine is running, there is no real reason for the designers of these car supplies to keep the quiescent current low.

Cigarette lighter plugs are also pretty lousy DC connectors. They often don't fit well and can easily fall out. With this project, you can use whatever type of connector is most convenient. In many cases, this will mean input wires terminated in spade or eyelet lugs.

While this may seem like a very specific application, there are many other uses for a low-quiescent current 12V DC to 5V DC converter. For example, remote monitoring stations often run from a 12V SLA battery topped up by a solar panel. These stations invariably contain a microcontroller and other circuitry which needs a 3.3V-5V supply.

The current consumption in these devices will be low most of the time but occasionally the microcontroller will wake up and activate a radio

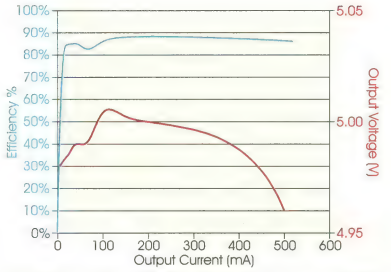


Fig.1: this graph plots the efficiency and output voltage over the full output current range. As shown, the efficiency is over 80% for any output current above 10mA.

module or other circuitry which can draw more current. This charger can deliver that current – up to 500mA – while still being miserly with battery power when the load is light.

In addition, because its efficiency is high (up to 89%), hardly any battery power is wasted even when the load is drawing 500mA.

What is quiescent current?

So what exactly is quiescent (or standby) current? This term often comes up in IC data sheets. Its simple meaning is "idle current", although when talking about regulators, it sometimes refers to the current consumed by the device itself, rather than by what it is supplying.

In most fixed regulators, this is the same as the "ground pin current". There are typically two current flows in a regulator – from the input to the output and from the input to ground. The ground pin current is the power consumed by the regulator itself.

At higher currents, most regulators consume more current than they do at idle. As a result, the quiescent current may be specified for different output currents, including the no-load case. Although the device is arguably no longer "quiescent" when it is delivering an output, the term is often used this way.

Since we primarily want to minimise power consumption with no USB device attached, the idle current is critical for this design. What's more, a device with low idle current will usually also have low ground pin current at higher loads. This is just what we want since the overall efficiency is determined by the combination of the conversion efficiency and ground pin current.

USB charging issues

Basically, this device is a DC-DC converter. You feed 12V DC (or thereabouts) in at one end and it delivers a 5V DC output at the other end. It complies with the USB 2.0 specifications with regard to power, ie, it supplies at least 500mA at 4.75-5.25V.

However, for some devices, this current level is insufficient for them to operate and charge their battery simultaneously. Many of these devices require a custom cable or special USB data pin connection arrangement before they will attempt to draw more than 500mA so that they can do both at the same time.

This shouldn't be a big problem since such devices should be able to operate without simultaneously charging the battery. The battery can then be charged when they are switched off (ie, no longer being used). Unfortunately, many USB-powered devices provide no way to switch modes like that. However, if your device can operate normally from a computer's USB port, it should work fine with this charger, since they supply the same amount of power.

There's just one wrinkle here. If your USB device switches to a data transfer mode when plugged into a computer USB port, it may behave the same way when connected to this charger, even though the data lines (D+ and D-) aren't connected. Its battery will still charge but the device may have to be unplugged to be used.

Devices which typically behave in this manner are car GPS units. Plug them into a PC's USB port and they immediately switch to data transfer mode (ie, for downloading software upgrades and map updates). This doesn't stop the internal battery from charging via the USB port – it's just the the device must be unplugged in order to use it as a GPS.

Design considerations

The first step in designing this device was to find an appropriate switchmode regulator IC. One candidate that satisfies all the requirements is the Linear Technology LTC1174HV. The HV (high-voltage) version can run from 6-17.5V (for 5V output) and consumes only 130µA at idle, with a maximum output of around 500mA (this is also the most current that can be drawn from a single USB port). The LTC1174HV is quite efficient too.

Unfortunately, it's hard to get the HV version in a DIP package. None of our usual vendors stock it, so we had to order the low-voltage version, which has an absolute maximum rating of only 13.5V.

This problem was solved by adding a low quiescent current linear preregulator to the design. This prevents the IC's supply from exceeding 13V, regardless of the battery voltage. The only drawback is that it reduces the efficiency slightly at higher battery voltages, although it doesn't add much to the idle current.

However, since the battery will only be above 13V while it is being charged, the loss of efficiency under this condition doesn't really matter.

The other issue is that while the data sheet says that switching will occur at around 100kHz with the components we are using, at light loads the burst mode causes switching to occur at much lower frequencies – in some cases, well into the audio range. As a result, the inductor used in the circuit makes some noise with light loads.

We managed to tweak the design to minimise this noise. If you listen carefully you can hear it but once the

Performance

Output voltage: 4.75-5.25V
Output current: approximately 525mA
Input voltage range: 6-16V DC
Input current requirement: maximum 300mA at 12.0V
Input current with output shorted: 4.3mA
Output ripple: 110mV p-p, 30mV RMS at 500mA
Load regulation: 50mV at 12V, 0-500mA (1%)
Line regulation: 16mV at 450mA, 7.0V-13.0V (0.32%)
No load input current: 160µA
Efficiency: up to 89% (see Fig.1)
Switching frequency: 10Hz – 120kHz

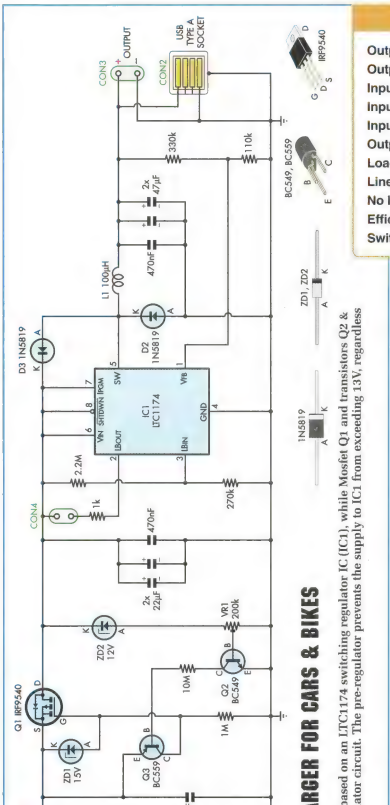


Fig.2: the circuit is based on an LTC1174 switching regulator IC (IC1), while Mosfet Q1 and transistors Q2 & Q3 form a pre-regulator circuit. The pre-regulator prevents the supply to IC1 from exceeding 13V, regardless of battery voltage.

board is mounted in a box and placed in a moving vehicle, it will be inaudible.

Circuit description

Refer now to Fig.2 for the circuit details. IC1 is the main switching regulator IC, while Mosfet Q1 and its associated parts form the pre-regulator circuit.

Power from the external 12V DC source is fed in via CON1. Immediately following this, a 36V AC transient voltage suppressor (TVS1) across the input damps any positive voltage spikes that may appear on the supply line (eg, due to devices switching on or off). Diode D1 then provides reverse polarity and negative spike protection.

The pre-regulator circuit (based on Q1) was published previously in Circuit Notebook for March 2010. It is a low quiescent current Mosfet-based design, especially developed for this type of application. Its operation was fully explained in the Circuit Notebook entry, so we'll just cover the basics here.

Essentially, the transconductance of the Mosfet Q1 is controlled so that the voltage at its drain will not exceed a preset value. This is done using zener diode ZD2, trimpot VR1 and transistors Q2 & Q3.

In this case, the voltage on Q1's drain is set to 13V and VR1 allows you to trim this value. We need to make sure the LTC1174 can't be damaged and this provides a small safety region (ie, 0.5V) between its supply voltage and its maximum rating.

The circuit works as follows. When power is applied, Q1's gate is pulled low via a 1MΩ resistor, turning it on. Q1's output voltage then rises until ZD1, a 12V zener diode, begins to conduct and pass current to trimpot VR1. Once VR1's wiper exceeds 0.65V, Q2 turns on and this then turns on Q3.

As a result, current now flows though Q3 and the 1MΩ resistor. This in turn increases Q1's gate voltage and switches it off. By suitably adjusting VR1, Q1's output can be accurately set to 13V.

The nominal 13V supply from the pre-regulator is decoupled using two 22µF 16V tantalum capacitors and a 470nF MKT capacitor. Tantalum capacitors were chosen for two reasons: (1) they have much lower leakage than aluminium electrolytics and (2) they have a lower ESR at high frequencies than other electrolytics.

Any capacitor leakage across the input or output of the switchmode regulator adds to the quiescent current of the circuit and we want to keep leakage to a minimum. The switchmode circuit can operate at frequencies in excess of 100kHz (occasionally as high as 1MHz) in burst mode, so we need to make sure the capacitors will be effective at high frequencies.

The switchmode regulator section is based on the schematic shown in the LTC1174 data sheet ("High Efficiency 3.3V Regulator"). However, the 50µH inductor has been increased to 100µH and we've added a voltage divider since we need a 5.0V output instead of 3.3V.

Pins 7 & 8 of IC1 are tied to the positive supply rail. Keeping pin 8 high ensures that the IC is always enabled, while pulling pin 7 high selects the higher peak current limit (600mA). That way, the current limiting will not kick in until an average of almost exactly 500mA is being supplied.

The 330kΩ and 110kΩ resistors across the output form a 4:1 voltage divider. This sets the output voltage. In operation, the LTC1174 adjusts its output voltage so as to keep its V_{FB} pin (pin 1) at 1.25V. This means that the output voltage will be 1.25 x 4 = 5.0V.

If you want to change the output voltage, use the formula R3 = R4 x $((V_{OUT}/1.25) - 1)$, where R4 is 110kΩ. For example, to set the output to 3.3V, replace R3 with 180kΩ. In this case, the output would be taken from CON3 (which is a polarised 2-pin header) rather than from the USB socket.

The 2.2MΩ and 270kΩ resistors form a voltage divider which is applied to the L_{BIN} (Low Battery Input) pin of IC1. If the supply falls below 11V, pin 2 will sink current (ie, it goes low). Header CON4 enables a high-brightness LED to be fitted to indicate the low-battery condition but note that once it comes on, it will then run the battery flat even faster!

In short, this LED is optional and should be left out unless you have a specific reason for using it.

By contrast, diode D3 is necessary. It's included to protect IC1 from an input supply short circuit – as unlikely as that may be. Without it, if an input short were to occur, IC1 could be destroyed.

Following L1 (which serves as the switchmode energy storage element), the output voltage is filtered by two 47µF tantalum capacitors and a parallel 470nF MKT capacitor. This is not a great deal of capacitance but thanks to the good high-frequency performance of tantalum capacitors, the output ripple is typically no more than 110mV peak-to-peak and 30mV RMS. Larger capacitors could be used here but their leakage currents would be higher.

The 5V output is fed to two different output sockets connected in parallel. CON2 is a Type A USB socket for recharging USB devices. For other devices, the output can be taken from 2-pin polarised header CON3.

Note that the operating temperature range for the LTC1174CN8 is specified as 0-70°C. If you live in a cold or extremely hot climate and will be using this device outdoors (eg, mounted outside the cabin of a vehicle), then you may need to use the LTC1174IN8 IC instead. This can operate from -40°C to 85°C.

Input limitations

Normally, the supply voltage will be in the range of 12-14.4V. However, the regulator will operate just fine over a range of at least 9-15.6V. In a vehicle, it is not unusual to get short-term voltage spikes in both directions. TVS1, D1 and the pre-regulator combine to protect the device from these spikes.

Voltages between -36V and 0V will not harm the regulator since D1 will not conduct. D1's reverse breakdown voltage is -40V but TVS1 should absorb spikes below -36V anyway.

Above 15.6V, the regulator will continue to operate normally, all the way up to 36V at which point the TVS clamps the supply voltage. We tested the regulator to 30V and it ran normally. However, if you were to run the regulator at high current and high voltage, Q1 would eventually overheat since it has no heatsink.

This means that while the regulator will run off voltages above 15.6V, as can happen in a vehicle from time to time, it must not be run at high voltages for extended periods. With a maximum input current of about 220mA at up to 15.6V, Mosfet Q1's dissipation will not normally exceed 572mW.

Parts List

1 PC board, code 14105101, 62 x 49mm
1 2-pin terminal block (5.08mm pitch)
1 PC-mount horizontal Type A USB socket (Jaycar PS0916, Altronics P1300)
2 2-pin polarised headers (2.54mm pitch)
2 2-pin polarised header connectors (2.54mm pitch)
1 100µH high-frequency 1.13A bobbin inductor (Altronics L6222)
1 small rubber grommet
1 M3 x 6mm machine screw
1 M3 star washer
1 M3 nut
1 8-pin machine tooled socket (optional)
1 200kΩ horizontal single-turn trimpot (VR1)

Semiconductors

1 LTC1174CN8 (IC1) (available from Farnell)
1 IRF9540 Mosfet (Q1)
1 BC549 transistor (Q2)
1 BC559 transistor (Q3)
1 1.5KE36CA transient voltage suppressor (TVS1)
1 12V 1W zener diode (ZD1)
1 15V 1W zener diode (ZD2)
3 1N5819 Schottky diodes (D1-D3)

Capacitors

2 47µF 16V tantalum
2 22µF 16V tantalum
2 470nF MKT
1 100nF MKT

Resistors

1 10MΩ	1 300kΩ*
1 2.2MΩ	1 270kΩ
1 1MΩ	1 110kΩ
1 360kΩ*	1 1kΩ
1 330kΩ	

* May be necessary to adjust regulator output – see text

Buck regulation

The LTC1174 has several modes but works similarly to a normal "buck converter" at high output currents.

A "buck converter" is the most common type of step-down DC/DC

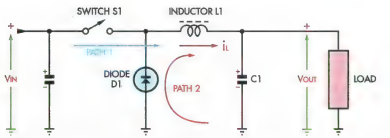


Fig.3: basic scheme for a switchmode buck converter. Voltage regulation is achieved by rapidly switching S1 and varying its duty cycle. Current flows via path 1 when S1 is closed and path 2 when it is open.

converter. It requires a single switch (normally a transistor), an inductor and a capacitor. Fig.3 shows the basic scheme and it works as follows.

When the switch is closed, current flows through inductor L1 into the load (Path 1). This current slowly builds up from zero to a peak value. When this peak current is reached, the switch opens and current flows through diode D1 to discharge the inductor's energy into the load (Path 2).

C1 is included to act as a reservoir, to smooth out the voltage produced across the load. This voltage is dependent on the load and duty cycle of switch S1 (ie, the time that it is closed compared to the time that it is open). It's also dependent on the peak current through L1 and the input voltage.

This type of circuit can be very efficient because voltage control is achieved by rapidly switching the input. The small amount of power dissipated is mainly due to voltage losses in the switching device (in practice, S1 is a switching transistor or Mosfet) and in L1 and D1.

The USB Charger operates in similar fashion but in this case the the switching is performed inside IC1 (LTC1174).

Many buck regulators operate at a fixed frequency, using PWM to control the switch duty cycle and thus the output voltage. By contrast, the LTC1174 has a "fixed off-time" configuration. It varies the switch duty cycle by controlling the length of the "on-time", ie, how long the switch is kept on for each pulse. This is a power saving feature – it means that the frequency drops at light loads and the less the internal Mosfet has to switch, the less power is consumed by the IC itself.

When the internal Mosfet switches on, current flows from V_{IN} (pin 6) to SW (pin 5) and through inductor L1, charging the output capacitors. During this period, the magnetic field generated by the inductor increases.

Conversely, when the internal Mosfet switches off, the magnetic field collapses and this continues driving current into the output capacitors. Since the internal transistor is off, the current instead flows from ground through D2 and then through the inductor.

It is this charging and discharging of the inductor's magnetic field which allows for efficient voltage conversion. When the internal transistor is on, the inductor nominally has 12V at its switch end and 5V at the output end. If the inductor was a resistor, then more than half the power would be wasted as heat.

There are losses in this process, which is why switchmode regulator efficiency is never 100%. However, it is still a great deal better than linear regulation. With a 13V input, a 5V output and 500mA output current, the input current is around 220mA. This gives an efficiency of (5 x 0.5)/(13 x 0.22) = 87%. A linear regulator under these conditions would have just 5/13 = 38.5% efficiency (assuming that the input and output currents are equal).

If the instantaneous current through the inductor exceeds the IC's internal current limit (nominally 600mA), the internal transistor switches off and the switch off-time is extended from 4µs to around 12µs. This gives the inductor time to discharge if the output is shorted.

One reason for this current limit, apart from stopping IC1's internal transistor from overheating, is that inductors with non-air cores can "saturate". Essentially, the core can only hold a certain amount of magnetic flux and its inductance rapidly drops when that level is reached. When it drops far enough, the inductor is essentially just a wire and if the switch is still on, a lot of current can flow through it.

Because the current through the inductor is ramping up and down as the transistor switches, the average current is less than the peak current. That is why, with a 600mA limit, we can only draw up to 500mA. The current limit kicks in soon after that and the output voltage drops until the current draw decreases below the limit.

This protects against short-circuits

Table 2: Capacitor Codes

Value	µF Value	IEC Code	EIA Code
470nF	0.47µF	470n	474
100nF	0.1µF	100n	104

Table 1: Resistor Colour Codes

❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	1	10MΩ	brown black blue brown	brown black black green brown
❑	1	2.2MΩ	red red green brown	red red black yellow brown
❑	1	1MΩ	brown black green brown	brown black black yellow brown
❑	1	360kΩ	orange blue yellow brown	orange blue black orange brown
❑	1	330kΩ	orange orange yellow brown	orange orange black orange brown
❑	1	300kΩ	orange black yellow brown	orange black black orange brown
❑	1	270kΩ	red violet yellow brown	red violet black orange brown
❑	1	110kΩ	brown brown yellow brown	brown brown black orange brown
❑	1	1kΩ	brown black red brown	brown black black brown brown

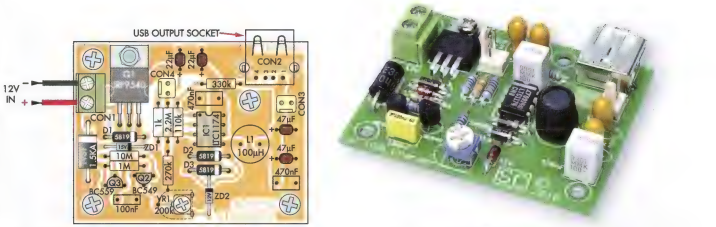


Fig.4: follow this parts layout diagram and the accompanying photo to assemble the PC board. Make sure that all polarised parts are correctly oriented and don't get the transistors mixed up.

at the output as well as inductor saturation.

Burst mode

At lower currents, the IC goes into "burst mode". What it does is deliver several very fast pulses of current to the inductor over a short period, bringing the output voltage slightly above 5V. It then switches off and waits for the output voltage to drop below 5V and then starts pulsing again.

As it is waiting for the voltage to drop, the IC is in "sleep mode" and consumes very little power. The result is that at light loads, ground pin current is substantially lower than it would otherwise be without this burst mode.

While the delay between the bursts makes the effective frequency of operation much lower than at full power, the frequency of the bursts themselves is actually quite high. We measured frequencies as high as 1MHz.

This means that the noise generated by the inductor is a sub-harmonic of the switching frequency and is caused by magnetostriction of the inductor's core.

If there is nothing attached to the regulator's output, the feedback voltage divider becomes the only load. Because the output voltage decays very slowly, the period during which the IC sleeps in burst mode becomes several hundred milliseconds. It is this long sleep period which allows the regulator to have a very low quiescent current with light loads or no load (approximately 140µA).

Construction

Building this unit is easy. All the parts mount on a small PC board coded 14105101 (62 x 49mm) and this snaps into the integral channels in a standard UB5 plastic box. The USB socket is accessed through a hole cut in one side of the box, while a hole at one end provides access to the input screw-terminal block.

If you want something that's a bit more robust, a small IP67-rated box can be used instead. In this case, the board can be mounted on M3 x 12mm tapped stand-offs and secured using M3 x 6mm machine screws and washers.

Note that because this unit is likely to be exposed to a lot of vibration, we have not specified a socket for the IC. You can use one if you prefer but make sure it is a machine-tooled type, as the IC is less likely to work its way loose.

Before starting the assembly, carefully check the PC board for defects. Most of the underside is covered by a ground plane. Make sure that there are no unintentional connections between this ground plane and any of the other tracks, as could occur if the board is under-etched.

If you are going to install the board in a UB5 case, check that it fits correctly by snapping it into place. It may be necessary to file the edges slightly if it is too large. Even if it's just 0.1mm too wide, that can make the plastic case bulge slightly when it is in place.

Once you are satisfied the board is OK, install the resistors. Check each resistor with a DMM before installing it on the board, to ensure the values are correct. That done, install the diodes, starting with the two zeners (ZD1 & ZD2), then the three 1N5819 diodes (D1-D3). Don't mix them up and be careful with their orientation.

Next, bend the Mosfet's leads down by 90° exactly 5mm from its body and mount it on the PC board. Check that its tab mounting hole lines up with the board, then fasten it to the board using a 3mm machine screw from the top and a star washer and M3 nut on

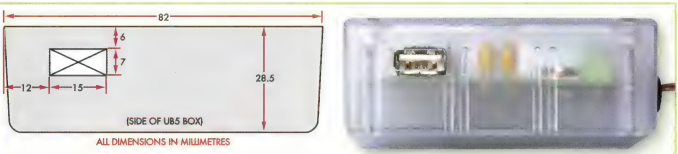


Fig.5: this diagram can be copied and used as a drilling template for the USB socket cut-out in the side of the case.

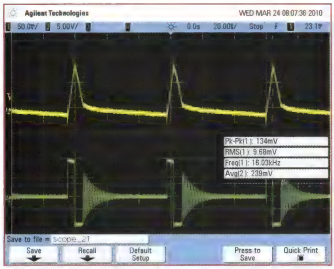


Fig.6: this shows the output voltage (yellow) and switching (green) waveforms at 10mA. The long off-time relative to the on-time can be seen. The device is operating in discontinuous mode – the inductor current falls to zero, causing the oscillations in the green trace.

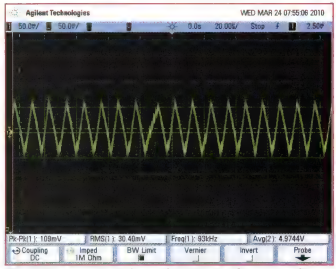


Fig.7: this scope shot shows the output voltage waveform at 450mA. The device is switching continuously and so the frequency is much higher. There is evidence of occasional burst-mode operation, as can be seen near the centre of the trace.

the underside. Do the nut up firmly, then solder and trim the leads.

Note: don't solder the Mosfet's leads first. If you do, you could stress and crack the the copper tracks on the PC board as the mounting screw is tightened. Always install the mounting screw before soldering.

Next, install the IC socket if you have decided to use one. Follow this with the transient voltage suppressor (TVS1) – its orientation doesn't matter – then install the two small-signal transistors (Q2 & Q3). Note that Q2 & Q3 are different types, so don't get them mixed up. Q2 is a BC549 NPN transistor, while Q3 is a BC559 PNP type.

If their leads are too close to fit through the holes, bend them outwards near the body of the transistor using small pliers, then back down again.

The PC-mount USB socket (CON2) is next on the list. Be sure to press it down firmly so that it sits flush against the board, then solder its two metal tabs to secure it in place. That done, solder the four pins, taking care to avoid bridging them.

Trimpot VR1 and the three MKT capacitors can now go in, followed by the four tantalum capacitors, inductor L1 (this can go in either way around) and the screw terminal block (CON1). Push the terminal block down firmly onto the board and make sure its entry holes face outwards before soldering its pins.

Be careful also with the orientation of the tantalum capacitors. A "+" will be printed on the case above the positive lead – just line it up with the "+" sign on the board overlay.

Vibration proofing

If the unit is to be used in a vehicle, it's a good idea to apply some silicone sealant around the base of each tantalum capacitor and TO-92 transistor. The idea is to glue them to the PC board so that they can't vibrate and break their leads.

Be sure to use neutral-cure silicone

Recharging Apple USB Devices

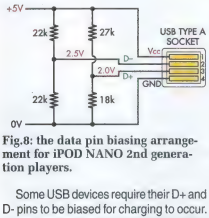


Fig.8: the data pin biasing arrangement for iPOD NANO 2nd generation players.

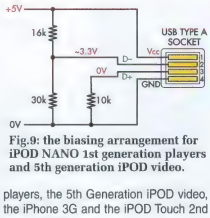


Fig.9: the biasing arrangement for iPOD NANO 1st generation players and 5th generation iPOD video.

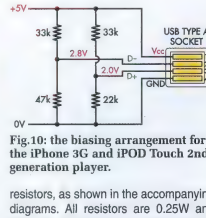


Fig.10: the biasing arrangement for the iPhone 3G and iPOD Touch 2nd generation player.

Some USB devices require their D+ and D- pins to be biased for charging to occur. These devices include the iPOD NANO 1st generation and 2nd generation music players, the 5th Generation iPOD video, the iPhone 3G and the iPOD Touch 2nd generation player.

This biasing can be achieved using resistors, as shown in the accompanying diagrams. All resistors are 0.25W and they can be installed by adding them to the copper side of the PC board.

sealant (ie, the stuff without acetic acid).

Set-up & testing

Before soldering in the IC, it's a good idea to adjust the pre-regulator voltage. To do this, connect a power supply which can provide somewhere between 14-30V to the input terminal block, with an ammeter in series. It's best to start at the lower end of that voltage range.

Turn on the supply and check the current. It should be less than 1mA. If it is more than 1mA, then something is wrong – turn it off and check for assembly errors.

Now check the voltage between pads 8 & 4 for IC1. It should be in the range of 12-14V. Adjust trimpot VR1 until it reads 13V (or just under). If you want to be extra cautious, you can set it to 12.5V for a slight loss in efficiency.

Once the reading is correct, disconnect the power and install the IC to the PC board. Make sure it goes in the right way around!

Now power the board using a 9-16V supply and check the output voltage. The easiest way to do this is to check the voltage across pin header CON3.

The output should be very close to 5.0V, or if you have changed the output divider, your target voltage. It will be moving up and down slightly due to the burst mode regulation but should not vary by more 0.2V. If it is not being properly regulated to 5V, disconnect the power and check for faults.

It's possible that the output voltage could be below 4.85V, due to a combination of the tolerance of the voltage feedback divider resistors and the tolerance of the LTC1174's internal reference voltage. If this is a case, replace the 330kΩ feedback resistor with a 360kΩ resistor. This will increase the output voltage by 6.8%, ensuring that it never drops below the minimum USB supply limit of 4.75V.

Conversely, if the output is above 5.2V, replace the 330kΩ feedback resistor with a 300kΩ resistor, to reduce the output voltage by 6.8%. However, in most cases, the output will be within 50mV of the programmed voltage with the recommended 330kΩ resistor.

Installation

If you are going to install the board in a UB5 box, you will first need to make a cut-out for the USB socket. Fig.5 shows the cutting details and this diagram can be copied and used as a template. You will also have to drill a hole in one end of the box to accept a grommet for the input leads or connector.

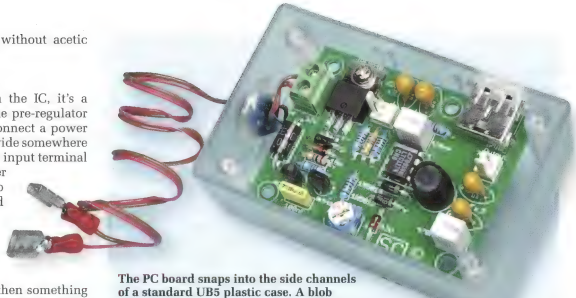
After that, the board should simply snap into place. It's best to introduce the side with the USB socket first and then gently push the board into place.

Alternatively, as previously stated, you can mount the board in the case of your choice and secure it on threaded standoffs using M3 x 6mm machine screws. A 500mA in-line fuse on the input side is a good idea, although the IC's current limiting should normally protect the power supply.

As a final check, once the supply is wired up, it's a good idea to use a multimeter to measure the voltage at the USB socket before attaching any devices. There are four pins in the USB socket – touch the multimeter probes to the two outer pins, being careful to avoid shorting them to adjacent pins or the surround. If the multimeter reads close to 5.0V (or your target voltage), then it's working properly.

That's it! If you are using the USB Charger to power USB devices in a vehicle, don't forget to unplug them when they are not in use, or you could still flatten the battery.

Alternatively, if you power the device via the cigarette lighter socket, it will be automatically switched off when the ignition is switched off. SC



The PC board snaps into the side channels of a standard UB5 plastic case. A blob of hot-melt glue can be used to stop the grommet for the input leads from working loose.

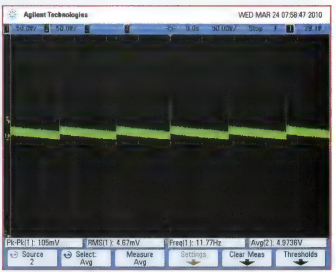


Fig.11: this shows the output voltage during standby operation. Note the low frequency of operation due to the long sleep time and burst mode.

In the March and April 2010 issues, we described the design and construction of our new Digital Audio Signal Generator. The final article this month has the driving instructions.

By NICHOLAS VINEN

A High-Quality Digital Audio Signal Generator; Pt.3

DRIVING THE Digital Audio Signal Generator is straightforward. In operation, it delivers an output signal (analog and/or digital, depending on the configuration) as soon as it is switched on and the LCD initially shows the current signal generation mode. There are five such read-outs, one for each mode: locked, independent, mixed, pulsed and sweep.

In each case, the Up and Down buttons change the current mode and the display adjusts to show the corresponding reading. Pressing the Select button (in the centre of the main cluster) switches the LCD from the signal generation mode read-out to the setting read-outs. When this is done, signal generation continues according to the last mode selected.

Changing the setting read-out (done using the Up and Down buttons) has no affect on the current signal generation mode. There are seven different setting read-outs. Pressing the Select button again returns the unit to the signal generation mode read-out.

In other words, the Select button toggles between the current signal generation mode read-out and the setting read-out. The active generation mode is always the mode which was last selected.

Left & right buttons

On most read-outs, the left and right buttons allow you to move a cursor across the display. The only exception is the Status read-out where these two buttons have other effects (more on this later). In practice, the cursor can only move to locations which show values that can be adjusted or activated.

When the cursor is visible, pressing the Up and Down buttons will modify the indicated setting rather than changing the current read-out. Pressing the Select button or moving the cursor past the first or last setting hides the cursor and the Up and Down buttons can once again be used to change the current mode and/or read-out.

This system may sound complicated but once you try it, it will quickly start to make sense. In other words, it

sounds more complicated that it really is and the process is quite intuitive once you understand the basics.

The mute buttons

There are two additional buttons on the unit – Left Mute and Right Mute. Pressing them toggles the mute status of the corresponding channel at any time. For example, if you press the Left Mute button and the left channel is currently enabled, it will be disabled and vice versa.

The mute status is shown on the status read-out and also on each mode read-out. For sweep mode, if a channel is muted, an "l" (indicating the left channel) and/or an "r" (indicating the right channel) is shown at the top of the display. For the other four modes, a muted channel is shown by changing the minus sign in front of each amplitude setting to an underscore.

If you press the two Mute buttons simultaneously, the left and right channel settings will be swapped. This includes frequency, amplitude and phase (when applicable), as well as the mute status.

Table 1 shows what each generation mode read-out looks like by default and highlights all the settings that can be changed. There is also a description of the function for each setting.

More mode information

As stated in the original article, the output frequency can be set at up to half the sample rate (ie, 48kHz) in steps of 1Hz. Depending on which frequency digit you select with the cursor, pressing the Up and Down buttons will add or subtract 1Hz, 10Hz, 100Hz, 1000Hz or 10,000Hz.

The amplitude is set in similar fashion and the range is from 0dB to -98dB in 1dB steps.

If you increase the attenuation past -98dB, the read-out changes to "off" and the signal is muted.

Note that as you get close to -98dB, the actual signal amplitudes become so small that the error increases and some values have an identical result. In fact -96dB, -97dB and -98dB generate the same amplitude due to the 16-bit precision of the scaling factor. However, for attenuation down to -60dB, the scaling is basically perfect. Beyond that, the measured values are as shown in Table 2.

Note that these measurements also include scaling errors from the DAC itself, so they are only a guide as to the unit's actual precision.

Table 1: Signal Generation Mode Readouts

1000Hz – 0dB 180° – 0dB	**Locked Mode Readout:** top line = signal frequency (both channels) and left channel amplitude; bottom line = channel phase difference and right channel amplitude.
L: 1000Hz – 0dB R: 1000Hz – 0dB	**Independent Mode Readout:** top line = left channel frequency and amplitude; bottom line = right channel frequency and amplitude.
A: 1000Hz – 0dB B: 1000Hz – 0dB	**Mixed Mode Readout:** top line = frequency and amplitude of wave 1; bottom line = frequency and amplitude of wave 2.
1000Hz – 0dB 100/900ms –30dB	**Pulsed Mode Readout:** top line = frequency (both channels) and pulse-on amplitude; bottom line = pulse-on time (0-9999ms), pulse-off time (0-999ms) and pulse-off amplitude.
20Hz – 0dB 20000Hz 10.0/ 1s	**Sweep Mode Readout:** top line = start frequency and amplitude (both channels); bottom line = finish frequency (both channels), sweep time (0.1 - 99.9s) and off-time (0-98s & manual).

Note: values inside green boxes can be selected and varied using the front panel pushbuttons.

Table 2: Attenuation Accuracy

Setting	Measured Value
-60dB	-59.92dB
-70dB	-69.80dB
-80dB	-79.16dB
-90dB	-89.35dB

Keep in mind that when adjusting the attenuation, pressing the Up button increases the attenuation and thus decreases the signal amplitude.

The only other mode settings (aside from frequencies and amplitudes) are time periods. In the case of pulsed mode, they are specified in milliseconds and have a range of 0-9999 (just under 10 seconds) or 0-999 (just under one second). In sweep mode, they are specified in tenths of a second and seconds, with a range of 0-99.9 seconds and 0-99 seconds respectively.

If you switch away from a mode and then back again later, the previous settings are typically retained. However, some are shared between the modes. For example independent and mixed mode share all their settings, differing only in how they output the signal (independently to each channel or mixed on both). As a result, changing a setting in one changes both.

The left/right channel amplitudes are shared between all modes except pulse and sweep. Most other settings are independent.

Configuration details

Table 3 shows each setting read-out and describes each field. Some require more explanation, as follows:

Status readout: the Status readout is very useful in sweep mode. Not only does it show the frequency as the sweep occurs (it's updated four times a second) but you can pause and restart the sweep. Pressing the Left button in this readout mode pauses or resumes the sweep, while pressing the Right button starts/restarts it.

This is especially useful when you are optimising crossover networks or matching a subwoofer to other drivers. If you hear a peak in the output amplitude, you can pause the sweep and read off the frequency.

There may be times when you want a manual sweep, ie, rather than having it loop repeatedly, you can trigger it manually. To do this, set the sweep off time to maximum via the sweep mode read-out – it will show "man" (manual).

It will then only start when you trigger it manually from the status read-out using the Right button.

Sweep setting readout: this simply allows you to choose between Exponential or Linear sweep. Exponential sweep is the default and is usually

Table 3: Setting Readouts

Rate: 48000Hz Wave: Sine	**Output/wave type setting read-out:** top line = output type (44100Hz, 48000Hz [default], 96000Hz, Analog); bottom line = signal type (Sine, Square, Triangle, SawtoothUp, SawtoothDn).
Status: Locked 1000Hz LR - 0dB	**Status read-out:** indicates the current generation mode and mute status. In pulsed and sweep mode, it shows the current frequency and amplitude. "LR" becomes "lr" when both channels are muted.
Sweep: Exponential	**Sweep setting read-out:** first line = setting; second line = sweep type (Exponential [default] or Linear).
Consumer Normal Battery: 4.800V	**S/PDIF setting read-out:** line 1 = encoding type (Consumer [default] or AES/EBU) plus pre-emphasis setting (Normal [default] or PreEmph); line 2 = battery voltage display.
3.3V Cal: 3.300V Low Bat.: 4.000V	**Battery setting read-out:** Line 1 = 3.3V regulator output voltage calibration; line 2 = low battery warning voltage setting.
Brightness: 25% Contrast: 50%	**LCD setting read-out:** line 1 = LCD backlight brightness (0-100%); line 2 = LCD contrast (0-100%).
Bank: 0 Load Save	**EEPROM setting read-out:** line 1 = Select EEPROM bank (0-9); line 2 = Load all settings from specified bank and Save all settings to specified bank.

Note: values inside green boxes can be selected and varied using the front panel pushbuttons.

what you want. In this mode, the frequency doubles or halves at a fixed rate.

Linear sweep simply increases the frequency by a set amount over time. As a result it spends less time at low frequencies and more time at higher frequencies. This mode could be useful if you are using a computer to capture and analyse the output, as it may make analysis simpler.

Keep in mind that while the generator attempts to reach your programmed finish frequency after the specified time has elapsed, in practice this is very difficult to achieve. As a result, with long sweep times, it may be off by a few milliseconds and occasionally the final frequency may actually be a few Hz below that specified.

S/PDIF setting read-out: this lets you configure the S/PDIF output format as well as view the current battery voltage.

The first setting, "Consumer" or "AES/EBU", determines the format of the Channel Status data sent with the S/PDIF stream. "Consumer" is the typical format that most CD and DVD players use. On some equipment, this format is limited to 20 bits of precision in the audio data, so you may get slightly higher distortion and worse amplitude control on this setting. However, it is the most widely supported.

"AES/EBU" is the professional standard used by DATs, mixers and high-end sound cards. It allows the full 24-bit precision in the audio samples as well as sending more complete meta-data. In general, AES/EBU mode is better provided the equipment that's receiving the signal can handle it.

The second setting allows you to enable the pre-emphasis bit in the S/PDIF stream. This has the effect of enabling the de-emphasis hardware in the receiver (if it has any) and is mainly useful for testing. For example, you can run a 20Hz-20kHz sweep with and without this bit set and check that the higher frequencies are properly attenuated (ie, de-emphasised) when it is set.

The battery voltage readout lets you keep track of the charge state. Note, however, that the reading is actually a little lower than the real battery voltage (by about 0.3V) due to the Schottky diode (D2) in series with it. This means that if you consider your cells flat when the battery reaches 4.0V (for example), you'll actually want to switch the device off or attach the plugpack as soon as it reads near 4.3V.

Battery setting readout: this lets you calibrate the battery voltage monitor – see the "Calibration" section in Pt.2 in the April 2010 issue. It also lets you set the low-battery warning voltage threshold. Once the battery has dropped below this level, the backlight will dim and flash, warning you to charge the battery or switch it off.

During this time, you can continue using the generator. The recommended settings are 3.9V for alkaline cells (actually 3.6V) and 4.3V for NiMH cells (actually 4.0V).

Regardless of this setting, if the voltage reading drops below 3.5V for some time, the microcontroller will go into sleep mode. The "Battery flat!" message is then displayed and all other functions cease. Backlight flashing continues although at a reduced brightness.

When that happens, the current drain drops from 100mA or more to about 30mA. This will still drain the battery but not as quickly.

LCD setting readout: here you can adjust the display contrast and backlight brightness. You may need to change them according to lighting conditions, viewing angle or temperature. If you manage to reduce the contrast so much that the display becomes unreadable, switching the power off and on will typically restore it to the default.

The backlight brightness selection is a compromise because as you increase it, you increase the current drain at the expense of battery life. The default value of 25% is sufficient for good display visibility under most conditions and only adds about 30mA to the battery current.

EEPROM setting readout: this lets you define the default settings (ie, those loaded at power on), as well as store up to nine other setting configurations. Bank 0 is loaded at switch-on, so if you save to bank 0 you are setting the defaults.

To save settings, select the appropriate bank number, then move the cursor to "Save" and press the Up or Down button. The read-out will change to "Saved" and the current configuration and mode settings will be stored in that

slot. You can then switch the generator off, or continue using it. You can even change the bank number and save to another one if you wish.

To load settings, the procedure is essentially the same. You select the bank number you want, move the cursor to "Load", and press the Up or Down button. The read-out changes to "Loaded" and the current settings are replaced with those stored in EEPROM. Almost everything will be set just as it was when you saved to that bank.

Note that attempting to load a bank that has nothing saved in it has no effect.

The additional banks can be handy if you often repeat certain tests and they involve a specific configuration. You can store commonly used configurations in banks 1-9 and save yourself the time of having to adjust multiple settings to the same values again later.

Wave types

Table 4 gives an example of each wave type. Each has been sampled using both the analog outputs of the Digital Audio Signal Generator and also the Silicon Chip High-Quality Stereo DAC (September-November 2009), the latter fed from the generator's S/PDIF output.

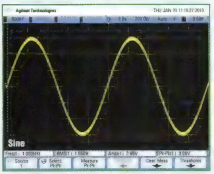
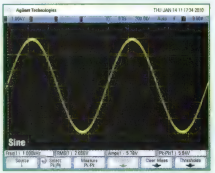
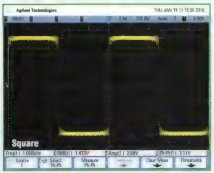
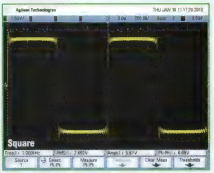
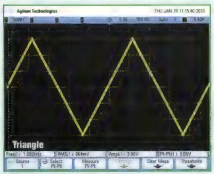
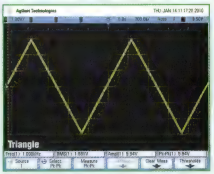
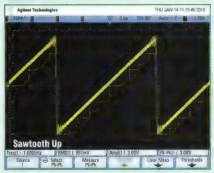
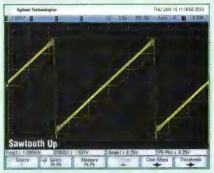
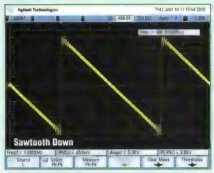
The high-frequency oscillations apparent in both the square and sawtooth signal outputs from both DACs are a result of their delta-sigma architecture. These types of waveforms are unnatural due to their discontinuous nature – ie, they contain vertical lines whereas natural waveforms normally do not.

As a result, the digital sinewave signal interpolation is smoothing the abrupt transitions, with the filter inserting some high-frequency waves before and after each transition to cover up the discontinuity. The result is what you see here. We know that the digital circuitry must be responsible for the oscillations because they occur equally both before and after each transition.

On the other hand, the external DAC has some overshoot with the square and sawtooth waves, which is presumably due to the analog filter circuitry after the DAC chip itself. It only occurs post-transition.

The sinewave signal does not suffer from this issue because it is continuous. The triangle signal does have a discontinuous first derivative (at the point of each triangle) but since it has a

Table 4: Example Wave Types

Internal DAC	External DAC
	
	
	
	
	

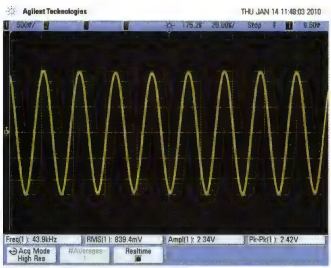


Fig.1: the effects of aliasing start to become noticeable at 44kHz. Note the subtle variations in the signal amplitude.

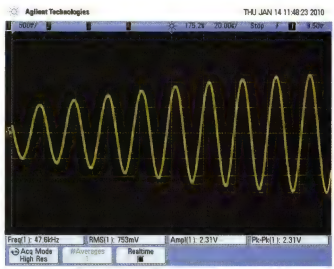


Fig.2: at 47kHz, aliasing effects are quite severe (the input data in this case actually has constant amplitude).

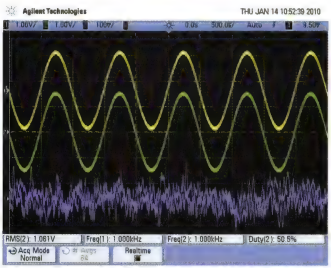


Fig.3: this scope grab shows the analog output distortion residuals (0.06%) for a 1kHz sinewave & 0dB attenuation.

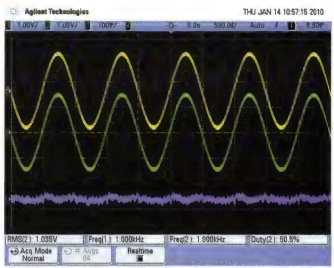


Fig.4: the distortion residuals drop to just 0.0006% (1kHz, 0dB attenuation) when using the High-Quality Stereo DAC.

continuous waveform it is not badly affected. There is a little rounding at the tips, again likely due to the digital sine signal interpolation, but it is minimal.

Aliasing

There is an additional issue related to the digital filtering and that is aliasing. In fact, all DACs suffer from it to some extent.

When the sample rate is set to 96kHz, the highest frequency signal you can generate is 48kHz. There is a wrinkle, though – as you get very close to 48kHz, there are so few samples per signal that the signal form can no longer be properly represented.

Basically, the digital data becomes ambiguous – while the frequency information can still be extracted, the amplitude of each wave is no longer clear. Aliasing starts to be become noticeable above 44kHz (note the subtle variations in amplitude shown in the scope shot of Fig.1) and it is quite severe at 47kHz (Fig.2).

The input data for the second capture actually has a constant amplitude. However, aliasing does not increase monotonically with frequency. There is no aliasing at exactly 48kHz, for example.

What this means is that you should generally avoid frequencies between 45% and 50% of the sample rate, except for exactly half (ie, 48kHz in this case). That way, aliasing will not typically be an issue.

By the way, if you want to make sound effects for a science fiction film, try setting the signal type to triangle and the sample rate to 48kHz, then initiate a sweep from 12-24kHz. What you then hear is due to the aliasing causing frequency shifts in the output.

Distortion

There's another issue to keep in mind when selecting the sample rate. When the output frequency is below about 10kHz, the sinewave signal distortion is actually lower at 48kHz sampling than at 96kHz sampling. So if you're only going to generate low-to-mid frequency sinewaves and need the least distortion, stick with the 48kHz sampling rate. You can still switch to 96kHz when necessary for higher frequency output signals.

Finally, if you have an oscilloscope, it's a good idea to connect the generator's outputs to it and try out the various modes. By doing this, you will quickly get used to the interface and get a feel for how the various modes work. **SC**

Tektronix DMM4050 6½ Digit Precision Multimeter

This bench-top multimeter features 6½ digit readings, a graphic LCD and a number of advanced features such as trend plot, histogram and dual measurement mode. With front and rear panel inputs, its short term and 1-year accuracy figures are outstanding.

Review by Nicholas Vinen

The Tektronix DMM4050 has all the usual features you would expect in a high accuracy bench-top multimeter.

The main modes are DC voltage and current, AC voltage and current (with true RMS), resistance (2- and 4-wire), continuity, diode testing, capacitance and temperature. Temperature measurement is via RTD (resistance temperature detector) only and can be use 2-wire or 4-wire sensing.

The unit measures 225mm wide, 330mm deep and sits 150mm above the bench surface when using the integrated carrying handle as a tilting bail (which provides two different angles). It comes with a pair of high quality needle probes, a power cable, an RS-232-to-USB cable and two CDs with documentation and software.

A calibration certificate is provided along with a booklet that contains installation and safety instructions, as well as listing the accuracy figures.

The basic DC voltage precision is 0.0024% over one year; other modes feature similarly excellent figures. Maximum DC voltage resolution is down to 100nV and DC current to 100pA.

Display, inputs & controls

One of the more outstanding features of this unit is the display. It is a wide-format cyan-on-black graphic LCD which is easily visible from any angle. There are three brightness settings available.

Having a graphic (dot matrix) display means that the format can change depending on the mode. For example, a larger font is used when taking a single measurement compared to dual measurement mode, making the display easier to read. The display also permits graphical features such as the trend plot and histogram.

In addition to the six banana sockets on the front, there are five on the back; the low current sense terminal is duplicated but the 10A terminal is not. Two buttons on the front panel switch between the two sets. This could be used for several purposes, eg, to switch between different sets of probes or for connection to an external test interface with less clutter.

Also on the rear panel are the external trigger terminal block, the Ethernet, RS-232 serial and GPIB (General Purpose Interface Bus) ports, the IEC power connector and the power switch.

All functions (including power on/off) are easy to access via the front panel buttons. The interface response is instant – the only time there is a noticeable delay is the first time the unit is turned on after being connected to mains power.

In any mode, extended functions are generally provided via the five "soft buttons" which are labelled at the bottom of the LCD. This allows them to change function to suit the mode. Less commonly accessed functions are available via the "Analyze", "Measurement Setup" and "Instrument Setup" buttons.

Features

Virtually all modes provide optional digital and analog filters to remove noise and high frequency variations from the readings. AC measurements can also be displayed in dB or dBm and have more filtering options. The diode tester has a few selectable voltage and current levels.

Most modes give a choice of 4, 5 or 6-digit readout and you can configure how many power line cycles (PLC) the readings are sampled over, for a speed/accuracy trade-off. The longer the sampling time, the less noise affects the reading.

The DMM4050's dual measurement mode is handy but more limited compared to some other bench meters. In DC volts mode you can also measure AC volts. In AC volts or amps mode you can measure the DC component or frequency simultaneously. In DC amps mode you can measure AC amps, DC volts or volt-amps. In frequency mode, period can also be displayed. In temperature mode, the sensor resistance can be displayed.

In DC volts mode, the default input impedance is 10MΩ but it can be set to 10GΩ for the 10V range and below. This could be critical for getting accurate readings on a voltage with a high source impedance.

There is another very useful DC voltage measurement feature: the sense terminals can provide a reference voltage and display the reading as a ratio to it. That could be

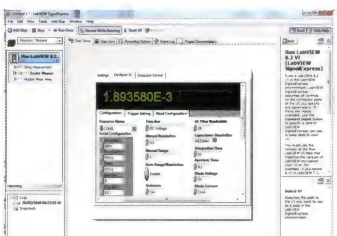


Fig.1: this PC screen shot of the provided software ("NI LabVIEW SignalExpress Tektronix Edition" Light Edition for Windows") shows the real-time reading taken from the DMM4050 along with the control panel which allows you to configure it from the PC. A USB-to-RS232 serial cable is also included.

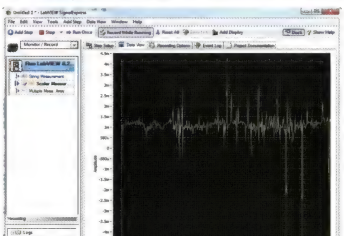


Fig.2: the software can log measurements over time and display them in an auto-scaled graph which is updated as measurements are taken.

The busy rear panel of the DMM4050. Along with the second set of inputs, there are the external trigger terminal block, the Ethernet, RS-232 serial and GPIB ports, the IEC power connector and the power switch.

handy for measuring voltage dividers etc.

The capacitance measurement range is from 1pF to 100,000µF – allowing measurement of virtually any capacitor you might come across.

The meter has quite a few mathematical and analysis features. Mathematical options include limit testing, offset nulling, arbitrary offsetting, ratio measurements and mX+B measurements. An interesting feature is "stats" mode which shows reading minimum, maximum, average and standard deviation over a configurable number of samples.

The DMM4050 can be triggered from an external source and can also send a pulse after each measurement is completed, via the 3-way terminal block mounted on the rear panel. The trigger delay and number of samples collected when triggered are adjustable via the front panel interface.

Storage and logging

The DMM4050 has a 10,000 reading internal memory and can also store multiple configurations internally, to save time repeating particular test set-ups.

If a USB flash drive is plugged into the front panel, it is possible to store another 999 files with the same 10,000 reading limit for each. This provides a handy way to get data to a computer for analysis regardless of where the meter is installed. Readings can also be saved to a USB flash drive from the internal memory.

The unit can be controlled and measurements taken from a computer via an RS232 serial interface, GPIB or over Ethernet. The supplied RS232-to-USB adaptor cable makes connection easy with virtually any modern computer.

"NI LabVIEW SignalExpress Tektronix Edition" (Light Edition) Windows software is included. With it you can control the meter and record the readings (see Fig.1 & 2).

Serial interface protocol documentation is also provided. This allows custom software to be written which has full control over the meter. For example, such software could allow for automated testing in a production environment.

While the built-in trend plot and histogram features of the meter are impressive, off-loading the data to a personal computer for analysis or plotting provides a great deal more power and flexibility.

Clever accessories

The DMM4050 has a very clever optional accessory – the TL705 4-wire test lead. It has just two banana plugs and two leads – in fact it is only superficially different from a regular set of probes in that both plugs are moulded from the same piece of plastic.

The trick is that the multimeter's input sockets have split contacts that allow all four wires to be connected with just two plugs. The TL705 leads contain a pair co-axial wires connected to copper-tipped Kelvin probes.

So despite being able to use them like regular probes, measurements down to a few milliohms are possible in the 4-wire mode.

The copper tips avoid any dissimilar metal junctions in the probes. Such junctions can act like thermocouples and bias voltage readings.

Conclusion

While the DMM4050 has a decent set of features, its focus is on precision. We can't list all of the accuracy figures here but the data sheet, available from www.tek.com, has that information. In this sense, you get what you pay for – the measurement errors of this unit are much lower than cheaper 6½ digit multimeters.

Many DMM4050 purchasers will also want to spend the extra for the TL705 4-wire test lead since it makes accurate resistance measurement so much easier and accuracy is this unit's forte.

Availability

The DMM4050 with a standard three-year warranty is available from TekMark for AU$1885 plus GST and delivery. The DMM4040 (without capacitance or temperature mode) is AU$1531 plus GST. The 5.5 digit DMM4020 is AU$1044.00 plus GST. To contact TekMark, e-mail enquiries@tekmarkgroup.com or call (02) 9911 3888.

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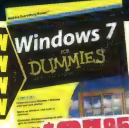

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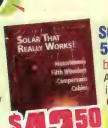

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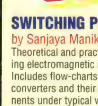

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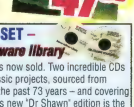

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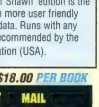

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Vintage Radio

Automatic gain control (AGC) – what it is & why it's necessary; Pt.1

Manufactured around 1948, the Astor GR/GRP receiver was a simple 3-valve TRF receiver. It had no AGC and featured a simple volume control which varied the back-bias on its 6G8G variable-mu RF valve.

The development of AGC (automatic gain control) circuits in the late 1920s and early 1930s was an important milestone in domestic radio receiver design. It allowed stations to be received at the same volume when tuning across the band, regardless of signal strength.

WHEN RADIO (or "wireless") first made its appearance, it was necessary for receivers to use every bit of RF (radio frequency) and audio frequency gain available. However, as receivers became more sensitive and gains improved, this situation quickly changed. Receivers became much more capable of pulling in weak signals but there was one drawback. If a receiver was tuned to a weak signal, the gain then had to be manually reduced when tuning to a strong station in order to produce the same audio output level or volume.

On a set with a loudspeaker, there would be a burst of quite loud and probably distorted audio until the volume control was hastily wound back. That was bad enough but if the listener was using headphones, their ears would be ringing for quite some time afterwards.

Once caught, most listeners would turn the volume control down while they tuned across the band. This meant that strong stations were easily heard but it had the disadvantage that weak stations might be inaudible. So it was a compromise as to just how far the volume control was wound back while tuning.

DXing

In the early days of radio, many listeners became interested in the hobby of "DXing" which involved receiving and identifying distant stations. Of course, these stations were much weaker than any local stations and it was all too easy to get a sudden loud burst of sound from the loudspeaker as one of the local stations was tuned.

Coupled with the inevitable static crashes, this ran the distinct risk of not only damaging the loudspeaker but also frightening hell out of the listener (and any innocent bystanders). Permanent damage to the listener's hearing was also possible if headphones were being used.

To minimise this problem, it was therefore necessary to keep one hand on the volume control as the set was tuned. That made tuning receivers with no AGC (automatic gain control) a rather tedious and awkward job.

In the simpler receivers, the regeneration control acted as the volume control but more complex receivers did have a separate audio-stage volume control. In fact, many of the more complex receivers were likely to have both audio and RF stage gain controls.

Another problem with early receivers was the variations in audio level due to signal fading. At night, the signal strength from a distant station often varied continuously, from almost non-existent at times to quite high at other times. This signal "fading" was inevitable and forced the listener to continuously vary the volume control to keep the audio at an almost constant level.

Distant stations were also likely to suffer from selective fading which introduced considerable distortion on AM signals. Unfortunately though, AGC cannot overcome this particular problem. It can be overcome to a large extent by using phase-locked single sideband (SSB) reception but this is a specialised technique that's used more in communications equipment rather than in domestic receivers.

The Mullard Meteor 600 4-valve receiver (circa 1947) was another economy receiver with no AGC. The volume was controlled by varying the back-bias to the first two valves (both variable-mu types) in the line-up (ie, to the ECH35 converter & EBF35 IF amplifier stages).

Enter automatic gain control

In summary then, the problem was how to stop the set from blasting the listener out of the room on strong signals while still allowing weak signals to be received at usable volume. The answer was Automatic Volume Control (AVC) or as we more accurately call it today, Automatic Gain Control (AGC).

Basically, AGC works by automatically reducing the gain of the receiver when a strong signal is received. The stronger the signal, the greater the AGC action. As a result, the audio output is kept reasonably constant for all stations regardless of signal strength.

AGC was invented in the US in 1925 by Harold Wheeler but did not come into common usage until well into the 1930s. However, some late-model TRF (tuned radio frequency) receivers using sharp cut-off valves did use AGC circuits. This was not particularly successful as only a very limited amount of AGC could be achieved before the valve cut off completely.

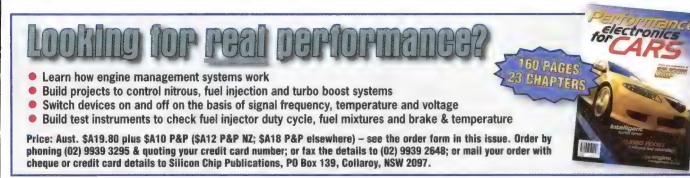
The designers understood that varying the bias on the valves could alter the gain to some degree. The problem was that the gain of sharp cut-off valves does not vary a great deal until the valve is actually near cut-off. Once the valve is near cut-off, very little increase in the bias voltage is needed to fully cut it off and reduce its gain (or amplification) to zero.

When these valves are near cut-off, distortion, overloading and various spurious signals are generated. This makes listening to an AGC-controlled set with a sharp cut-off valve rather unpleasant. This can occur if, say, a 6AU6 is plugged into the valve socket for an RF or IF stage designed to use a 6BA6 with AGC. The cut-off voltage for the 6AU6 is between -4V and -6V, depending on the operating conditions set for the valve. However, it is around -20V for a 6BA6.

The main difference between these two valves is the structure of the signal grid. The 6AU6 has a grid which consists of close, evenly-spaced turns of wire. By contrast, the 6BA6 has closely-spaced turns of wire at each end of the grid structure, with the spacing widening towards the centre of the grid. This is known as a "variable mu" valve.

Progressive cut-off

In operation, as the negative voltage on the grid of a variable mu valve increases, it progressively cuts off the electron flow at the ends of the grid structure. Eventually, with increasing negative bias, only a small section in the middle of the valve is left to do



First marketed in 1954, the AWA Radiola 653P was a 5-valve portable with simple AGC applied to the RF amplifier and converter stages.

the amplifying. However, because the remaining grid structure is so open, large AGC voltage variations now cause only relatively small changes to the plate signal, compared to when the entire valve is operating.

As a result, the gain is progressively and smoothly reduced as the grid bias increases.

Remote cut-off valves

Two early remote cut-off RF tetrodes were the 35 and 51. Introduced around 1931, they were nearly identical and became the 35/51. Basically, they were an adaptation of the sharp cut-off 24 but with a variable-pitch grid.

In operation, the 24 required just -8V of bias to cut it off but the 35/51 required around -40V. In addition, the latter's gain was reduced smoothly as the bias increased.

The 39/44 RF pentodes with remote cut-off characteristics appeared a little later, followed by the 58. More modern valves with remote cut-off characteristics include the 78, 6D6, 6U7G, 6K7, 6SK7, 6AD8, 6AR7GT, 2B7, 6B7, 6B8G, 6G8G, 6BA6, 6BH5, 6BY7 and the 6N8. The relevant battery valve types include the 1D5GP, 1C4, 1M5G, 1P5G and 1T4.

The AGC voltage

Having established that varying the negative bias on a remote cut-off valve would alter its gain, it was necessary to come up with a method of developing this control voltage. The device that found almost universal favour to do this was the humble diode detector.

Some receivers did use valves that acted purely as diode detectors, eg, the 6H6 and the 6AL5. However, valve envelopes were expensive and as the manufacturers became even more innovative, they included one and sometimes two signal diodes in the same envelope as an audio triode. Basically, the cost of producing a valve with two diodes and a triode was not much more than the cost of producing a single-function valve.

The 55 and the 85 are two such triode/diode valve types. In each case, the triode section was similar to the proven 27 valve. They were successful and this prompted the development of similar valve types, some even including tetrode or pentode elements.

The 55 and 85 are not the same, however, as their triode gains are quite different. The 85 has a gain of about six while the 55 (or, in its octal guise, the 6SQ7GT) has a gain of about 60 in a practical circuit. Other valves that proved successful in the duo-diode audio triode role are the 2A6, 6B6G. 6BD7 and the 6AV6.

The duo-diode audio triode valve suited the standard 5-valve superhet receiver, which used a converter, an IF (intermediate frequency) amplifier, a combined detector and first audio stage, an audio output valve and a rectifier. By contrast, economy sets using just four valves omitted the first audio amplifier. As a result, in these sets, the detector and AGC diodes were incorporated into the IF amplifier valve, eg, the 6AR7GT, 6G8G, 6AD8, 6N8 and EBF35 (to name a few).

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The impressive 5-band STC Capehart A8551 radiogram dates from the mid-1950s and uses eight valves plus a magic-eye tuning indicator. It is also fitted with a very effective delayed AGC system.

One or two audio output pentodes had diodes built into them too, such as the 6BV7.

Early problems with AGC

Once suitable valves had been developed, AGC certainly kept the audio output level reasonably constant, even with wide variations in signal level. It made normal signal level fading much easier to accept but "selective" fading still made listening to distant stations difficult. It did take set designers a few years to get AGC systems working really well, however.

One early problem brought about by AGC occurred because of the way some people tuned their sets. AGC meant that the audio output level remained virtually the same even if the station was slightly mistuned. As a result, many users had difficulty in accurately tuning their sets even though a mistuned station resulted in audible distortion and sibilants and was unpleasant to listen to (I know because my father could never get it right, so I'd sneak up and retune the set when he wasn't looking).

Eventually, some manufacturers solved this problem by fitting "magic-eye" valves to many of the up-market receivers. The pattern on the magic eye indicated the correct tuning position.

Another early problem with AGC was that it emphasised the hiss, crackles, pops and other forms of interference when tuning between stations. That's because the sets were at their most sensitive when tuning between stations due to the increased gain. As a result, set manufacturers came up with various schemes to minimise this problem.

These schemes invariably used the AGC voltage to forward bias a valve or diode in the signal path when the signal exceeded a preset level. However, although these systems worked, any station that was only just strong enough to reach the threshold would give distorted audio. In addition, if the RF signal strength was fading up and down, it may be heard quite well for a short time but then, as it faded down below the threshold level, the audio would suddenly disappear before suddenly reappearing again as the signal level increased.

This system is called "Quiet Automatic Gain Control", or QAGC. And although it wasn't particularly successful on early domestic receivers, variants of it are still used in com-

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Photo Gallery: Fisk Radiola Model R49G

RELEASED IN 1939, the AWA Fisk Radiola Model R49G was a 4-valve battery-operated receiver that operated on the broadcast band. It was housed in an attractive wooden cabinet, had an IF (intermediate frequency) of 460kHz and included following valve line-up: 1C6 converter, 1D5G IF amplifier, 1K6 IF amplifier, detector, AGC & audio amplifier and 1D4 audio output. Photograph by Kevin Poulter for the Historical Radio Society of Australia (HRSA). Phone (03) 9539 1117. **www.hrsa.net.au**

munications receivers. However, it is now called "Mute" or "Squelch" and even some domestic FM receivers use a muting circuit to reduce noise between stations.

To overcome the limitations of QAGC, a number of manufacturers designed receivers with preset tuning. However, although the idea was fine, this meant that the frequency stability of the local oscillator had to be very good, otherwise the set would eventually drift off station. When this happened, the oscillator had to be serviced, which was very inconvenient and costly for the owner.

Mechanical preset tuning was subsequently used extensively in car radios in the 1960s but by then oscillator frequency stability was much better than in 1930s receivers.

Simple & delayed AGC

Initially, AGC circuits were of the simple variety, in that as soon as a signal, no matter how weak, was presented to the diode detector, a bias was applied to the AGC line. This meant that the receiver's gain on even quite weak signals was reduced. In fact, the noise picked up by the antenna when the receiver was tuned off-station was often enough to generate some AGC bias and this was used in some receivers as the standing bias for the AGC-controlled valve stages.

It might seem poor design to reduce the gain of a receiver when it is receiving an extremely weak signal. In practice, however, this did not really cause a problem, as it was quite practical to slightly reduce the standing bias on the AGC-controlled valves to make up for this. In these sets, a single diode usually performed the dual function of detector and AGC diode.

By contrast, delayed automatic gain control (DAGC) uses two diodes – one as the detector and the other as the AGC diode. The detector circuit is usually the same as in sets with simple AGC.

DAGC is obtained by biasing the second diode so that it does not conduct until the signal voltage applied to it is above a preset level (usually between -2V and -3V). The AGC bias developed once that level is reached is then applied to the AGC-controlled valves in much the same manner as for simple AGC. However, by delaying the application of AGC until the preset level is reached, DAGC allows a receiver to amplify weak signals at full gain.

Early servicing problems

In earlier times, radio servicemen were mostly self-taught. As a result, many didn't understand AGC circuits and so were reluctant to work on them. There was a widespread belief in the trade that they were difficult to work on but this was mainly due to their lack of knowledge and adequate test equipment.

What made it hard was that AGC circuits have high resistance values and the average serviceman had ineffective instruments for testing them. As a result, servicemen often had to guess whether this part of the circuit had a problem in it.

Remember also that components were expensive in those days. When I was servicing back in the late 1950s, my wages were $18 per week and a standard RF valve cost $2 or $3. Capacitors were around 15 cents each, so radio parts in earlier times were much more expensive in relation to the average wage. These days, we can afford to replace multiple components when tracking down a fault but that technique wasn't economic until the 1980s.

Next month, we'll take a look at a variety of AGC circuits and describe how they work. We'll also take a look at some of the faults which can be found in such circuits. SC

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Changing the Zapper to suit 8V batteries

I recently purchased and built the Battery Zapper (SILICON CHIP, May 2006) and it works perfectly. However, is it possible to change the 6V setting to 8V or 9V. There are a lot of 8V batteries used in golf carts etc. I feel that it would be better to treat batteries independently instead of in 24V banks, don't you?

I would use a 9VDC 1A plugpack during zapping and then revert to the normal 48V charger when zapping is completed. (T. Q., via email).

● We would suggest treating 8V lead-acid batteries independently instead of in 24V banks.

Only one modification is needed to change the 6V range for checking 8V batteries. This involves swapping the connection from the "6V" position of switch S2b from the junction of the 270Ω and 220Ω resistors in the metering voltage divider down to the other end of the top 220Ω resistor (ie, to the junction of that resistor and the 220Ω resistor below it).

However, for improved operation of the Condition Checker section of the project, we suggest that you also make some of the changes incorporated into the "Mk3" battery checker which was described in the August 2009 issue.

Manual controller for thermoelectric cooler

I want to build a simple controller to manually adjust a 96W 12V thermoelectric cooler. Your 12V Speed Controller/Lamp Dimmer project (SILICON CHIP, November 2008) seems ideal but only handles up to 50W. The earlier 12V/24V 20A design featured in the June 1997 issue is more than I need (and costs twice as much).

Can the 12V Lamp Dimmer be upgraded to handle a 100W cooler by simply changing the Mosfet? If so, which component should I use in place of the one included in the kit? (R. M., via email).

● For an 8A load, the MTP3055 is not suitable (as you suggest) because it is only rated at 12A and has an on-resistance of 0.15Ω. Its dissipation would be just under 10W at full power to the motor. It therefore should be changed to an IRF1405 (169A, 5.3mΩ). This has a much lower on-resistance, so there will be less heat generated within the Mosfet.

The fuse should be rated at 10A and the tracks leading from the screw connectors to the fuse, the Mosfet's drain and source and to diode D2 should be thickened by running solder along the tracks or add some tinned copper wire between the connections on the PC board if it is solder-masked.

24V mod for battery charge controller

Would it be possible to use the 12V Battery Charge Controller from the April 2008 issue for 24V batteries? I expect the voltage divider involving R1 and R2 would need to be changed to match the 24V rail but could I leave the rest basically alone having consideration for the larger heat dissipation? (C. M., via email).

● For charging 24V batteries, R1 should be 12kΩ and R2 2.2kΩ. The 470µF 25V capacitor at the input should be increased to 35V or 50V, while the 100Ω 0.5W resistor in series with switch S1 should be 220Ω 0.5W.

Using a relay to change motor direction

I've purchased two PWM controllers (SILICON CHIP, June 1997) to control two 200W 12V fixed magnet brushed motors. I am wondering if I can run these motors also in reverse by putting a switch in after diode D2 and the capacitor which are wired across the motor, to reverse the polarity at the motor. (A. J., via email).

● Yes, a DPDT (Double Pole Double Throw) relay can be used to switch the polarity applied to the motor terminals. For these relays, there are two separate contacts called poles and each pole has a common (COM), a normally-open (NO) and a Normally-Closed (NC) contact.

Twin Settings For 12V Battery Charge Controllers

I have built six 12V Battery Charge Controllers (SILICON CHIP, April 2008) for the club VHF/UHF repeaters, myself and several others. They seem to perform excellently.

However, for the first time, I needed two sets of parameters for different charge rates. It seems that I cannot do this because setting trimpots VR1-4 on link 5 also sets those parameters on link 6. That means that I cannot set two sets of values and switch them via a 2-way switch, connected to the pins of links 5 and 6, on the front panel.

The instructions read as if two sets of parameters can be set, stored and changed at will with links 5 and 6. Can you help me, please? (T. B., North Albury, NSW).

● You can have two sets of parameters and switch between them with LK5 and LK6.

With LK5 inserted, adjust the required parameters using trimpots VR1, VR2 and VR3 for one type of battery and press switch S2. Then use LK6 and set the parameters again using VR1, VR2 and VR3 and press S2. This will make the two alternative parameter settings available, depending on whether the LK5 or LK6 setting is being used.

The VR1-VR3 settings are dual-purpose and set the parameters depending on the position of LK5 and LK6. These settings are not stored unless S2 is pressed. This is detailed at the end of the article headed "Setting the parameters".

If we call the poles Contacts 1 and Contacts 2, then the COM terminal of each pole connects to each of the motor terminals. The NO of contact 1 and the NC of the contact 2 connect to the "+" output of the Motor Speed Controller. The NC of contact 1 and the NO of the contact 2 connect to the "-" output of the Motor Speed Controller. The diode connects across the NC of contact 2 (cathode) and the anode to the NO of contact 2.

Note that for a 200W motor you would need at least 20A and preferably a higher contact rating for the relay. Also the motor should be stopped before switching it to change direction, otherwise the surge current will be very high.

External power supply for Class-A amplifier

I built the 15W Class A Amplifier some years ago and have enjoyed it tremendously. I have now purchased the Altronics kits for the new 20W Class Amplifier (ie, L & R channel amplifier kits and a power supply kit).

I wish to use the toroid from the original 15W amplifier which is 160VA and has 21V secondaries rather than purchase a new one with 16V secondaries. I'm happy to keep the new power supply in a separate box.

Can I use the regulated 20V supply from the original design? Alternatively, what changes would I need to make to the new unregulated supply in order to use the 160VA/21V toroid? (A. F., via email).

- If you are going to keep the original power supply box, then there is nothing to stop you from using the original power supply itself.

A new use for the GPS Car Computer

I have a possible application for the GPS Car Computer (SILICON CHIP, January & February, 2010). I drive a Toyota Camry V6 and a Proton Jumbuck ute which has a 1500cc 4-cylinder, both of which have air-conditioning. In South Gippsland where I live, the Proton ute is often one gear better off on long hills with the air-conditioning off and while there is no noticeable difference with the Camry, it would undoubtedly save petrol on those occasions when it is working hard on a hill.

My suggestion is that a combination of high fuel consumption and possibly higher revs without a proportionate distance travelled could be used as parameters to turn off the air conditioning compressor until conditions revert to more normal settings. Presuming the car computer is receiving pulses from an injector, all the necessary external data is already available.

This would also come into play under acceleration which is a feature appealing to the sports car fraternity. An override may be necessary when towing. (J. M., via email).

- We did publish an air-conditioning controller in January 2007. This optimised the compressor running for best economy and allowed extra power on acceleration. This approach would be much simpler.

Nitrous fuel controller is not working

I have constructed the Nitrous Fuel Controller (Performance Electronics for Cars, 2004) and on applying 12V DC with a 5W globe to check its operation, I found that it starts up only now and then and when it does, the frequency and pulse width jump all over the place. I had the board checked for soldering defects and incorrect placement by staff at the Jaycar store at Mermaid beach and they said my construction was spot on and the soldering was excellent.

I also found the 100Ω resistor and 12V zener diode (ZD1) were overheating (you could fry an egg on them). I have replaced the 7555 timer, trimpot VR1 and the MTP3055 Mosfet with no success. When I turn the trimpot the light changes intensity and flashes erratically. Please help. (G. C., via email).

- Check the positioning of transistors Q1 and Q2. The heavy load current causing the 100Ω supply resistor to overheat is possibly due to Q1 and Q2 being in the wrong positions. This would also cause the erratic behaviour.

Halogen lamps with dimmers

I am a little confused on the subject of using halogen downlights with light dimmers and hope that you can help. I have always thought that at a certain filament temperature, the tungsten

Noise-Cancelling Circuit Wanted

Recently, I built a Bionic Ear (Jaycar Cat. KJ-8226). I have used the unit in conjunction with a parabolic reflector and recorder to record bird calls in the bush. One problem that I have encountered is relatively high levels of ambient noise.

I have written to Jaycar suggesting that they consider developing a kit which incorporates a variable noise-cancelling feature. This would involve the use of two microphones. The first microphone faces the direction that the sound the listener wishes to hear emanates from. The second microphone registers the ambient sound. The second microphone's signal is then electronically subtracted from the first microphone's signal so that the difference is basically the sound that the listener wishes to hear.

Such set-ups have been used in hearing aids for some time. I believe that, some years ago, your magazine featured a project which involved an audio amplifier similar to the Jaycar kit. I realise that this noise-cancelling feature adds to the complexity of the unit and as such may be considered for a standalone project for inclusion in your magazine. (G. H., Camden, NSW).

- While we are not familiar with the Bionic Ear project, it is evidently similar in principle to the "Sooper Snooper" project described in the September 2001 issue.

The fact that you are experiencing a lot of extraneous noise suggests that your mike set-up may not be sufficiently directional. This may be because your parabolic dish is not big or deep enough or perhaps the microphone is not set at the focus of the parabola.

Having said that, we did describe a project with noise-cancelling microphones in an FM Motorcycle Intercom (SILICON CHIP, October & November 1989) and the relevant part of the circuit with noise cancelling could be adapted to your application.

How Do Electromagnetic Waves Penetrate Barriers?

I've been reluctant to ask this question for fear that it may be regarded as dumb!

For many years, I've remained curious as to how electromagnetic waves could possibly penetrate barriers such as brick walls, internal stud and plaster walls, and especially the metal-clad bodies of trains, trams, buses, various other motor vehicles, ships and aircraft, so that mobile phones, GPS devices, laptops and AV senders can happily work.

I'm happy with the thought of radiation from the Sun penetrating glazing, giving a potential window to EM radiation. However, with the relative absence of glass, how does EM transmission successfully penetrate all those barriers, particularly metal?

I also had in mind Faraday mesh shields for exclusion of EM radiation. Presumably mobile phones etc will not work inside such shields. Yet how do the phones and other electronic devices work within steel-clad bodies?

What finally triggered this enquiry was a recent comment in SILICON CHIP that the "GPS Clock" will even work inside a steel filing cabinet. Huh?

Hot on the heels of this dilemma was an enquiry from a colleague regarding the failure of a cordless phone to work inside a dwelling with multiple internal brick walls. There may be another logical reason for this aberration and I'm mindful of the fact that I've used a cordless telephone inside and outside our home (with multiple "barriers" to EM radiation) without trouble for many years. Conversely, a fairly typical AV sender installation has been disappointing.

So I'd be very grateful if you could put me out of my misery; curiosity is getting to me! I'll assume it's related to the wavelength of the radiation but I'm not entirely satisfied with the hypothesis, nor the physical realisation. My enquiry could even form the basis for a more detailed article in SILICON CHIP, assuming that many other readers might have similar doubts, simply accepting that what occurs is "normal" without understanding why. (B. G., via email).

● That is a big subject. Electromagnetic waves will certainly penetrate solid materials such as brick walls but they are heavily attenuated, depending on the moisture content of the material. Multiple brick walls inside a dwelling can cause a great deal of RF signal attenuation which can be a real problem if you are attempting to set up a WiFi network or A/V transmitter in a home.

Solid metal stops all RF signals, as will wire mesh, provided the signals of interest have a larger wavelength than the holes in the mesh. That is why mobile phone signals can easily be received inside a vehicle – the signals come in via the windows.

The reason that GPS signals can be received inside a filing cabinet is that the metal drawers and their fronts are not a tight fit. The signal can easily pass through the gap and while it is probably heavily attenuated in the process, there is still enough signal for the GPS receiver to work – incredible but true.

atoms liberated from the filament react with the gas and the glass envelope in a way that results in the tungsten being deposited back on the filament, thereby increasing the operating life of the lamp.

If I'm correct, it would stand to reason that using a halogen downlight with a light dimmer would reduce the lamp's life due to the fact the filament would not reach the required temperature for the abovementioned reaction to take place. This has me confused, because everywhere I go I see halogen downlights used with dimmers.

My question is does using a light dimmer with a halogen lamp reduce the lamp life?

● For the halogen cycle to work, the silica glass bulb itself must run at such a high temperature that tungsten is not deposited on it. Hence any atoms driven off the tungsten filament are eventually deposited back onto it.

When run with a dimmer, the halogen lamp runs much cooler and therefore the halogen cycle does not work. Lamps continually run in a dimmed condition will eventually blacken and will have a shorter life. Apart from that, running halogens with a dimmer greatly increases their inefficiency – it's a bad idea but people like the facility of a dimmer.

Modifying the Energy Meter

I would like to use the Appliance Energy Meter (SILICON CHIP, July & August 2004) to measure the electrical power used in my home workshop. My workshop has a single phase sub main protected by a 63A circuit breaker. The total rated load is 14.5kVA, so obviously the Energy Meter would need to be modified.

I propose using a 60:5 current transformer to measure the current in the sub main Active. I would delete R2 and move R1 so that it connects between the two 1kΩ resistors at the input of AMP1. R1 would serve as the shunt load for the CT and its value would be changed to 0.02Ω .

Using a 60:5 CT with a shunt load (R1) of 0.02Ω would give the same input to AMP1 of 100mV RMS at 60A load and 150mV RMS at 150% rated load. As I do not require the brown-out protection option, I propose deleting LK1 & 2, the 10Ω & 68Ω resistors, relay RLY1, D6 and Q1, as well as all of the load side wiring.

I would also change the value of F1 to, say, 1A as it would only protect the mains voltage sense circuit and the mains side of T1.

I have two questions: how do I scale the output to give the correct readings and will the phase shift adjustment be sufficient to deal with any phase shift introduced by the CT?

I think I may have the answer to question one. I have a copy of Geoffrey Graham's C code for this project (thanks, Geoffrey). In his code, he reads the watts value from the ADE-7756AN but before using it he divides it by 472,149, which he describes as a calibration constant.

If I divide this value by 6 and use 78,691.5 as my calibration constant, this should (I think) get me close to

displaying the correct power value.

I am a qualified electrician so there are no problems for me doing my own electrical work. (B. P., Murrumbateman, NSW).

● A current transformer could be used to reduce the current as measured by the Energy Meter. The phase adjustment in the ADE7756AN is there to compensate for current transformer phase shifts and so will provide sufficient adjustment.

Calibration has more to do with the actual numbers displayed on the LCD. So when the calculations have been made, the values will need to be multiplied by 6 when the 60:5 current transformer is used and R1 changed to 0.02Ω instead of 0.01Ω. However, the calibration constant of 472,149 could be changed to 78,691 instead.

Float charger modification for 24V

I have built several 12V SLA Float Chargers (SILICON CHIP, March 2003) to avoid sulphation in stored batteries. I now need to do the same for a 24V battery.

Could I have your advice please on some circuit changes? I have a 25V transformer and will raise the voltage rating of the filter capacitors. My real query is about the output voltage divider chain. I propose doubling the values: 120Ω to 240Ω, 1kΩ to 2kΩ and VR7 to 1kΩ. Any comments? (K. O., via email).

● For 24V operation, the 16V and 25V capacitors need to be rated at 50V. Both 2.2kΩ resistors feeding the LEDs should be 4.7kΩ. The series 1kΩ resistor and trimpot VR7 should be 2.2kΩ and 1kΩ respectively. Do not double the 120Ω resistor.

Also the relay should preferably be a 24V type (eg, Altronics S4162A) and the 220Ω 0.5W resistor supplying the relay current should be changed to 1kΩ 0.5W. Alternatively, if the original 12V relay is retained, then the 220Ω 0.5W resistor would need to be changed to 820Ω 5W.

In addition, take care that the input voltage to the LM317T does not exceed 40V.

Knock sensor for a go-kart

I bought the Knock Sensor kit (SILICON CHIP, June 2007) to use with the Ignitech CDI I use on my super kart.

The Ignitech has a function whereby when pin X is grounded, the timing is retarded. When I build the Knock Sensor kit, what type of output will it give when knocking is detected? Is it a positive voltage? If so, I will use a very small solenoid to earth the pin in the CDI or is there another part of the circuit I can tap into? I am using a GM knock sensor out of a 2000 V6 Commodore. (J. J., via email).

● The knock sensor project was specifically designed to be used in conjunction with the SILICON CHIP Programmable Ignition system (March to May 2007). It is not designed to pro-

... continued on page 95

Digital Camera Won't Work With Rechargeable Cells

A few months ago I made the mistake of buying an Olympus digital camera. This particular model takes two AA cells but will not run off rechargeables because the voltage is too low. Alkalines last about 15 shots. Lithiums are the only remaining alternative but they are expensive.

What if I was to somehow mount an extra rechargeable cell externally and connect it in series with a power diode? This should result in (3 x 1.2) - (0.6) = 3V. What are your thoughts on this arrangement? (G. H., Mt Martha, Vic).

● Unfortunately, the voltage drop across a silicon diode is not constant and increases with current. So if you have a nominal 3.6V from the NiMH cells, the voltage following the diode could range from about 3.3V at light loads to below 2.6V under load. This lower voltage may prevent the camera from working and the higher voltage at low loads may cause damage to the camera, as freshly charged NiMH cells can have a much higher voltage than 1.2V per cell.

If you are prepared to risk it, you could try the diode in series with the cells. A 3A diode would probably be required and maybe a Schottky diode would be needed to provide a lower voltage drop at high current.

Ideally, a better approach would be to use a 3V regulated supply that can deliver the required current for the camera. Lithium cells are probably the best alternative.

Notes & Errata

Battery Capacity Meter, June 2009: the circuit on page 22 shows pins 15 & 16 of IC1 reversed. The PC board is correct and does not need to be modified.

WARNING!

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Ask SILICON CHIP – continued from page 93

vide a knock signal independently from the Programmable Ignition which monitors the knock sensor signal only during the period of ignition and ignores the signal otherwise.

For use with the Ignitech CDI, the knock signal will require further processing where the output signal is monitored to produce a low-going (grounded) voltage with knock detection. A means to switch low when knock is detected would be required. The Voltage Switch (SILICON CHIP, December 2008) would be suitable.

Note that the 10nF capacitor connecting to pin 12 of IC1 in the Knock Detector will need to be increased in value to around 1µF to increase the signal detection period so that ignition retard will have time to take effect.

Changing the knock signal frequency

My engine knock frequency is at 6.8kHz but the low-pass filter in your Knock Detector circuit is set to 6.4kHz. I can't find any software to recalculate the low-pass to higher values. Is it possible to use precision trimmers to set the knock frequency window with a few modifications? Can I add a microcontroller to the output with 5V ADC? (J. B., Barkau, Germany).

● The low-pass filter can be changed to suit a knock frequency of 6.8kHz by decreasing the 3.3nF capacitor to 2.7nF and increasing the 12nF capacitor to 10nF. The signal output can swing to not much more than 5V, as IC1d's output does not go to the full supply of 8.2V.

The 2.2kΩ series resistor will limit current into a microcontroller's ADC input when the input protection diode clamps and prevents damage should signal output go above 5V.

Knock indicator to avoid engine damage

I have a couple of project suggestions that may be of interest to SILICON CHIP. They are along the lines of the salvaged parts series a while ago.

The first is an analog meter utilising a stepper motor as the movement with, say, a 0-1V or 0-0.1V input for full-scale deflection. A meter such as this could have numerous applications where an analog indicator with a quick response that's free of overshoot is useful. Dumped computers with floppy drives are plentiful on the streets these days and can be a source of stepper motors.

Secondly, how about an engine knock detector? It could be as simple as having just a warning light giving indication of single or continuous engine knocks and utilise a commonplace sensor. (A. G., via email).

● We produced a Knock Indicator for cars in the April 1996 issue. It used an LM3914 bar graph indicator and 10 LEDs to show the severity of knocking.

Simulating a knock sensor signal

I have purchased the article on the Knock Detector (SILICON CHIP, June 2007) and would like to know if this can be used on its own with a LED to detect knock in a engine while I am tuning it.

At this point, I am not sure what the output is between 4.8kHz and 6.4kHz because I cannot simulate this signal to see if the unit works. Your help would be appreciated. (L. N., Johannesburg, South Africa).

● As noted elsewhere on this page, the Knock Detector is not suitable for use as a standalone knock indicator. That function would be better performed by our Knock Indicator from our April 1996 issue. While there is no kit available for this project, all the parts are still readily available.

Having said that, you would probably be better off monitoring the knock sensor signal with an oscilloscope. Ideally, you should use a dual-trace oscilloscope so you can also display the ignition signal for each cylinder compared with engine firing. Knock will precede the ignition signal in each case.

To find out what the knock signal looks like, just gently tap the sensor with a screwdriver. SC

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Advertising Index

4D Systems 94
Altronics ..... Flyer
Aust. Valve Audio Transformers 95
Cleverscope 9
Dick Smith Electronics 24-25
Emona Instruments 41
Front Panel Express 11
Grantronics 94
High Profile Communications 95
Instant PCBs 95
Jaycar IFC,45-52,96
Keith Rippon 95
Kitstop 94
LED Sales 94
Oatley Electronics ..... IBC
Ocean Controls 10
OzComfile 94
PCBCART 11
Pymble Software 95
Quest Electronics 94
Radio, TV & Hobbies DVD 23
RCS Radio 94
Rohde & Schwarz 3
RF Modules OBC,96
Sesame Electronics 94
SC Performance Elec. For Cars 85
Silicon Chip Binders 87
Silicon Chip Bookshop 82-83
Silicon Chip Order Form 89
Siomar Battery Engineering 7,95
Soundlabs Group 9
Splat Controls 94
Terry's Transistors 94
Trio Smartcal 5
Truscotts Electronic World 95
Wagner Electronics 43
Worldwide Elect. Components 96

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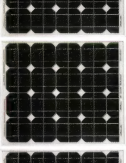

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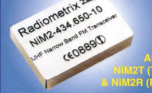

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